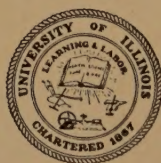


PETROLEUM
DEVELOPMENT
AND TECHNOLOGY
1937

PETROLEUM DIVISION

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OF THE

AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS

(INCORPORATED)

and Petroleum

Vol. 123

PETROLEUM DEVELOPMENT AND TECHNOLOGY

1937

PETROLEUM DIVISION

PAPERS AND DISCUSSIONS PRESENTED BEFORE THE DIVISION AT LOS ANGELES,
CALIFORNIA, OCT. 1 AND 2, FORT WORTH, TEXAS, OCT. 8 AND 9,
1936 AND AT NEW YORK, FEB. 15-19, 1937.

NEW YORK, N. Y.

PUBLISHED BY THE INSTITUTE

AT THE OFFICE OF THE SECRETARY

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THE MAPLE PRESS COMPANY, YORK, PA.

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FOREWORD

I take pleasure in commending to the members of the Petroleum Division this volume of TRANSACTIONS, Petroleum Development and Technology, 1937. The abundance of excellent papers presented at the meetings at Los Angeles, Fort Worth and New York has permitted and necessitated a very critical selection. Although this is the largest volume of the series since 1928, and contains approximately 150 more pages than last year, space limitations again necessitated omission of some papers.

The Petroleum Division was distinguished last year in that a member and former chairman, John M. Lovejoy, was president of the Institute and headed the official party that attended the Los Angeles and Fort Worth meetings. The former was the largest meeting the Petroleum Division has ever held on the Pacific Coast and more sessions were held and papers presented than ever before. The two-day session at Fort Worth covered a great variety of subjects and was well attended, as usual. The New York meeting, in addition to technical papers, was featured by a symposium on Stabilization, ably led by Earl Oliver, at which the chief speaker was Congressman Pettengill. Many distinguished executives as well as engineers attended and participated in the discussion.

Under the guidance of President Lovejoy, awarding of the Anthony F. Lucas Gold Medal, "for distinguished achievement in improving the technique of finding or producing petroleum," was initiated. The first medal was presented at the New York meeting, to J. Edgar Pew, Vice-president of the Sun Oil Co. and member of the Institute since 1917.

Such success as the Division has attained this year is due to the cooperative efforts of so many people that individual mention is impractical. The names of the officers and committee members, almost every one of whom has been active, are on pages 11 and 12 of this volume. Their efforts would have been useless without the efforts of those who have prepared and presented papers and to whom thanks for the contents of this volume are directly due. No organization such as the A.I.M.E. can exist without a permanent headquarters staff, and the A.I.M.E. is fortunate in having a staff that effects the smooth functioning of its many activities. Apparent to readers is the excellent editing and composition not only of this volume but of all Institute publications.

Respectfully submitted,

HALLAN N. MARSH, *Chairman,*
Petroleum Division, 1936.



PLANS FOR PETROLEUM DIVISION FOR THE YEAR 1937

BY M. ALBERTSON CHAIRMAN OF DIVISION

FOLLOWING the usual custom, three meetings are planned for the year. The Mid-Continent meeting will be held at Oklahoma City, Okla., Oct. 7 and 8, and the California meeting is planned for Los Angeles, probably also early in October. A program along the usual lines is under way for the annual New York meeting.

Discussion and planning of the year's activity started in March. An effort is under way to secure papers dealing with some overlapping phases of engineering, petroleum geology, geophysics, law, economics, refining, etc. The main reason for attempting a program along these lines is the belief that unusually interesting technical papers can be obtained.

The degree of specialization in the technical and related fields has permitted but few individuals to develop a sufficiently comprehensive viewpoint. Also, at times the developments in a particular field are capable of giving great stimulus toward much needed solutions of difficult problems in others fields of activity. With the coming of the period of restriction of production to market demand, many changes have occurred in policy and technique of petroleum production. Some changes have been advances, others have been of retrograde nature. It seems doubtful whether the adjustment to the condition of excess producing capacity has been complete or sound in some major respects. Many changes are in progress and others need to be initiated.

The industry has excessive producing capacity so far as immediate market demand is concerned, but reserves for several years hence are generally believed insufficient. Exploration and discovery should go forward but development should proceed with caution and under control. Property rights should be clarified and protected for the new condition—without excessive cost for drilling wells that serve no purpose except that of giving some protection to property rights at the cost of an increased price to the consumer.

Under the more steady condition of assured supply for the immediate future, as compared to the hand-to-mouth condition of wide-open production, a greatly advanced technique of development and production is possible and is being developed. Great progress has been made, but much remains to be done. Along some important lines progress can be effected only by better understanding between the engineer and the geologist, the lawyer, the politician, the geophysicist, etc. There is need

for a much fuller understanding of engineers in the social and political influences of their accomplishments. In short, men active in each branch, instead of proceeding independently of the others, should learn to coordinate with other branches and press forward in harmony toward a sound objective. This objective may well be the most complete and most economical extraction of the petroleum needed for common welfare.

For the foregoing reasons, it seems desirable to have technical programs that assist in developing a broader and more comprehensive understanding of the problems existing in the petroleum industry and, where feasible, in applying engineering technique to their solution.

The effort to make MINING AND METALLURGY interesting to men in the petroleum industry and to others having a general interest in the industry, initiated last year, will be continued.

An attempt to improve the organization and functioning of the Petroleum Division is having attention. The rapid growth of petroleum engineering, and the great increase in the number of technical graduates and engineers employed in production activity calls for improved opportunity for open discussion of views, and for more frequent effective personal contact of those engaged in the petroleum engineering branch of the profession. In short, the Petroleum Division should be organized so as to more completely fill the requirements of one of the most rapidly developing branches of engineering.

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THE ANTHONY F. LUCAS GOLD MEDAL

IN 1936 the Institute established the Anthony F. Lucas Gold Medal, which will be awarded from time to time "for distinguished achievement in improving the technique and practice of finding and producing petroleum." These awards will be sponsored by the Petroleum Division.

Captain Lucas was a pioneer in the oil industry, one of the early wildcatters and a leading mining and petroleum engineer. He was famous as the discoverer of Spindletop. He became a member of the Institute in 1895 and in 1913 was the first Chairman of the Petroleum and Gas Committee of the Institute, the forerunner of the present Petroleum Division. He also headed the Committee in 1914, 1917 and 1918.

The first medal was presented at the annual dinner in 1937, Feb. 17, to J. Edgar Pew.

The personnel of the Committee on award as appointed in February, 1937, is as follows:

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Anthony F. Lucas Medalist, 1937 Award

Chapter I. Production Engineering

The Sucker-rod Pump as a Problem in Elasticity

BY JOHN F. KENDRICK* AND PAUL D. CORNELIUS†

(Fort Worth Meeting, October, 1936)

THIS paper is a progress report of a study the authors are making of the sucker-rod pump, considered as a vibrating system with one degree of freedom, with forced vibrations and with viscous damping. Dr. S. Timoshenko's formula is given, defining such a system. Each factor is considered in respect to the problem of operating sucker rods, and the zone is pointed out in which the mathematics do not apply to the sucker-rod pump, because of its variable mass. This general theory is interpreted in the light of nearly two years of testing wells in the field, and correlating the results of other tests.

The motion of the pumping mechanism is a vibration. The string of sucker rods vibrates with a natural frequency. The motion of the plunger is the result of adding together these two vibrations, and is modified by a damping or friction factor. The controlling factor appears to be the ratio of the period of the natural vibration of the rod string to the period of the vibration of the pump. The first conclusion is that a definite value of this ratio, which is below resonance and is probably not greater than 0.5, should not be exceeded in order to assure satisfactory performance from the sucker rods. The second conclusion is that the component parts of the pumping equipment should be selected to give the smallest practical period of the natural vibration, and when this does not permit operation at a safe speed and give the required plunger displacement, a longer polished-rod stroke should be used.

While the quantitative results are but rough approximations, the qualitative analysis of pumping problems on this basis promises to be of considerable value in diagnosing the cause of poor performance and prescribing suitable remedies.

The trouble that results, whenever it becomes necessary to crowd the sucker-rod pump, to take potentials or to handle increasing volumes of water, is responsible for the belief that this type of pump is not equal to present day needs, and that it is only a question of time before some other pumping device will take its place. Of the troubles experienced, it is not surprising that the frequency of sucker-rod failures should

Manuscript received at the office of the Institute Sept. 8, 1936.

* Engineer, Pumphead Division, Sullivan Machinery Co., Tulsa, Okla.

† Manager, Pumphead Division, Sullivan Machinery Co.

increase under such conditions, but few anticipated that the majority of such failures would occur at some point below the top rod, where the maximum stress is assumed to be. Again, where high percentages of salt water have to be handled, the production does not keep pace with increased polished-rod velocity, but approaches a definite limit. It was assumed that such wells were pumped down, until it was discovered that this occurs even with a high bottom-hole pressure, indicating that the cause is not the lack of proper submergence.

The inertia theory of plunger reaction is entirely inadequate to account for such phenomena, but the newer vibrational theory supplies rational explanations for these and other observations. For instance, it indicates that the stress in one of the lower rods can be greater than the stress in the top rod, which could be suspected from the fact that the rods break there. Also, the theory shows that under conditions of high damping, which exist when the percentage of water is high, the plunger will understroke rather than overstroke, and the plunger will understroke more and more, as the speed is increased. However, the theory goes further than this, by calling attention to what should be done to make the sucker-rod pump equal to the pumping job.

This promise of usefulness has prompted the writing of this progress report, although much work remains to be done. More rapid progress should result, if more investigators are familiar with the fundamentals and are working along much the same lines. So these fundamentals will be found set forth in considerable detail in what follows, and interpreted, as far as possible, from the experience gained by two years of testing wells in the field and correlating other tests.

A weight tied to the end of a chain of rubber bands is a convenient device for observing the possible reactions of the plunger. It is a good analogy, except for the fact that the weight of the model is constant throughout a cycle, while it varies in the pump from the weight of the rods less friction on the downstroke to the weight of the rods plus the fluid and friction on the upstroke. Our experience, so far, indicates that this is of importance at slow speeds, where there is generally no serious sucker-rod problem, and is of no particular importance at the higher speeds. However, it is probably the main reason for actual performance departing from the theory.

As a visual demonstration of certain reactions of the plunger will be helpful in understanding what follows, we will run through the experiment with the rubber bands quickly. If we move the hand holding the upper end of the chain of rubber bands up and down slowly, imitating, as nearly as possible, the motion of the pumping mechanism, we observe that the weight or "plunger" moves with a "stroke" about equal to that of the "polished rod." As we increase the strokes per minute of our hand, we note that the "stroke" of the plunger increases and appears

to pass through a maximum. Thereafter, as the pumping speed is increased further, the "plunger stroke" becomes smaller and smaller, approaching zero as a limit.

Now we will shut off the power and let our pumping unit stop. Then we will pull the weight down about an inch and release it. The weight bobs up and down with decreasing amplitude and shortly comes to rest. This is the natural vibration and its period in seconds depends on the mass and elasticity of the system. The fact that these vibrations die out rapidly is a demonstration of viscous damping, which here is due mostly to the resistance of the air. If the experiment were performed in a vacuum, it would take a longer time for this vibration to die out, but the weight would come to rest eventually, due to hysteresis in the spring.

FACTORS IN PROBLEM

In their elementary forms, therefore, we have three factors: (1) the motion of the pumping unit, which can be considered a vibration with definite amplitude and frequency; (2) the natural vibration of the system with its definite amplitude and frequency; (3) a frictional or damping factor. Therefore, if we imagine the weight of our model guided by the walls of a glass tube, representing the tubing of an oil well, we have what the mathematicians call a vibrating system with one degree of freedom, with forced vibrations and with viscous damping. In such a system, the reaction of the weight or plunger is the result of adding together the two vibrations; that of the pumping mechanism or the forced vibration and that of the system itself, the natural vibration, and this resultant motion is further modified by the friction or damping factor. Therefore, we are able to recognize the point in our experiment at which the weight vibrated with its greatest amplitude, as the point of resonance, or the point at which the periods of the two vibrations are equal.

Dr. S. Timoshenko has given us the following formula, defining the resultant vibration of such a system:

$$d_3 = \frac{d_2}{\sqrt{\left(1 - \frac{T^2}{T_1^2}\right)^2 + \frac{T^2}{T_1^2}u^2}} \quad [1]$$

where d_3 = half plunger stroke, in.

d_2 = half polished-rod stroke, in.

T = period of natural vibration, sec.

= $0.3195\sqrt{d_s}$ where d_s equals the static stretch equivalent to the weight of the fluid and one-third the weight of the rods.

T_1 = period of forced vibration of pumping mechanism, sec.

= 60/s.p.m.

u = damping factor.

TABLE 1.—*Plunger-stroke Factors*
Solution of Formula 1

T/T_1	DAMPING FACTOR									
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.1	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
0.15	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.01
0.2	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.03	1.03	1.02
0.25	1.07	1.07	1.06	1.06	1.06	1.06	1.06	1.05	1.04	1.04
0.3	1.10	1.10	1.10	1.09	1.09	1.08	1.08	1.07	1.06	1.05
0.35	1.14	1.14	1.14	1.13	1.13	1.12	1.11	1.10	1.09	1.07
0.4	1.19	1.19	1.19	1.18	1.17	1.16	1.15	1.13	1.11	1.08
0.45	1.25	1.25	1.24	1.24	1.22	1.20	1.19	1.17	1.14	1.12
0.5	1.33	1.33	1.32	1.31	1.29	1.27	1.24	1.21	1.18	1.14
0.55	1.44	1.44	1.42	1.40	1.37	1.34	1.30	1.26	1.21	1.17
0.6	1.56	1.55	1.54	1.51	1.46	1.41	1.36	1.31	1.25	1.19
0.65	1.73	1.73	1.70	1.65	1.59	1.51	1.44	1.36	1.29	1.22
0.7	1.96	1.94	1.89	1.81	1.72	1.62	1.52	1.41	1.32	1.23
0.75	2.28	2.25	2.16	2.03	1.88	1.73	1.59	1.46	1.34	1.25
0.8	2.78	2.71	2.54	2.31	2.07	1.86	1.67	1.50	1.36	1.25
0.85	3.60	3.45	3.05	2.66	2.28	1.97	1.73	1.53	1.36	1.23
0.9	5.30	4.79	3.83	3.03	2.45	2.05	1.75	1.52	1.34	1.20

T/T_1	DAMPING FACTOR									
	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9
0.1	1.01	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.99
0.15	1.01	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.98	0.98
0.2	1.02	1.01	1.01	1.01	1.00	1.00	0.99	0.98	0.97	0.96
0.25	1.03	1.02	1.02	1.01	1.00	0.99	0.98	0.97	0.96	0.95
0.3	1.04	1.03	1.02	1.01	1.00	0.98	0.97	0.96	0.94	0.94
0.35	1.06	1.04	1.03	1.01	1.00	0.97	0.96	0.94	0.93	0.91
0.4	1.07	1.05	1.03	1.01	0.99	0.96	0.94	0.93	0.91	0.89
0.45	1.09	1.06	1.04	1.01	0.98	0.95	0.93	0.91	0.89	0.86
0.5	1.11	1.08	1.04	1.01	0.97	0.94	0.91	0.89	0.85	0.83
0.55	1.13	1.09	1.04	1.00	0.96	0.93	0.89	0.86	0.83	0.79
0.6	1.14	1.09	1.04	0.99	0.94	0.91	0.87	0.83	0.79	0.76
0.65	1.15	1.09	1.03	0.98	0.93	0.88	0.84	0.80	0.76	0.73
0.7	1.15	1.09	1.02	0.96	0.91	0.85	0.81	0.77	0.74	0.70
0.75	1.15	1.08	1.00	0.94	0.88	0.83	0.78	0.74	0.70	0.67
0.8	1.15	1.05	0.97	0.91	0.85	0.80	0.75	0.71	0.68	0.64
0.85	1.12	1.02	0.93	0.88	0.82	0.77	0.72	0.68	0.65	0.61
0.9	1.09	0.99	0.91	0.84	0.79	0.74	0.69	0.65	0.61	0.58

T/T_1	DAMPING FACTOR									
	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9
0.1	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.98	0.97	0.97
0.15	0.98	0.97	0.97	0.96	0.96	0.95	0.94	0.94	0.94	0.93
0.2	0.96	0.95	0.94	0.94	0.94	0.93	0.92	0.91	0.90	0.89
0.25	0.94	0.93	0.92	0.91	0.90	0.89	0.88	0.87	0.86	0.84
0.3	0.92	0.90	0.89	0.88	0.86	0.85	0.83	0.82	0.81	0.80
0.35	0.89	0.87	0.87	0.84	0.82	0.81	0.79	0.77	0.76	0.74
0.4	0.86	0.84	0.82	0.80	0.78	0.75	0.75	0.74	0.72	0.70
0.45	0.83	0.81	0.79	0.76	0.75	0.73	0.71	0.69	0.67	0.66
0.5	0.80	0.78	0.75	0.73	0.71	0.68	0.67	0.65	0.63	0.61
0.55	0.77	0.74	0.71	0.69	0.67	0.65	0.63	0.61	0.59	0.57
0.6	0.74	0.71	0.68	0.66	0.63	0.61	0.59	0.58	0.56	0.54
0.65	0.70	0.68	0.65	0.62	0.60	0.58	0.56	0.54	0.52	0.51
0.7	0.67	0.64	0.62	0.59	0.57	0.55	0.53	0.52	0.49	0.48
0.75	0.64	0.61	0.59	0.56	0.54	0.52	0.50	0.49	0.47	0.45
0.8	0.61	0.58	0.56	0.53	0.51	0.49	0.47	0.46	0.44	0.43
0.85	0.58	0.55	0.53	0.50	0.49	0.47	0.45	0.44	0.42	0.40
0.9	0.55	0.53	0.50	0.48	0.46	0.44	0.43	0.41	0.40	0.38

The derivation of this expression will be found in a number of the standard texts on elasticity, which are listed in the bibliography. It is integrated from differentials built up from trigonometric functions, and the two vibrations are sinusoidal in character. In this respect, the formula should apply to pumping units employing the walking-beam principle, which are variations of simple harmonic motion, better than to fluid motor types of motion, where the polished-rod velocity may vary inversely with the load. However, the experimental work indicates, so far, that these latter cycles follow the relationship close enough for practical purposes, although they generally show a smaller damping constant, presumably because of their lower peak velocity. The relation-

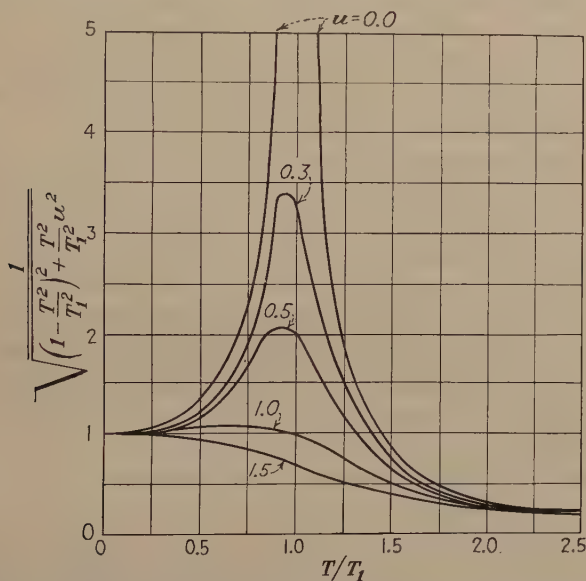


FIG. 1.—CHARACTERISTICS OF VIBRATING SYSTEM WITH ONE DEGREE OF FREEDOM AND WITH FORCED VIBRATIONS. (After Timoshenko.)

ship is evolved with the assumption of a constant mass, and the mathematicians claim they cannot integrate the differentials, if they allow for a variable mass. This appears to introduce a serious error at very low speeds only, where the vibratory stresses are not a serious factor. At the higher speeds, the formula gives sufficiently close results for our purposes.

The solution of this formula 1, for various values of T/T_1 and u , will be found in Table 1.

In order to assist in visualizing the significance of this fundamental relationship, Dr. Timoshenko has plotted it as a family of curves, which is shown as Fig. 1. It will be noted that the horizontal scale is the ratio of the periods of the two vibrations T/T_1 . It will be found helpful to

regard this scale as polished-rod velocity or strokes per minute, which could be substituted for any given well. This relationship is as follows:

$$N = \frac{60R}{T} \quad [2]$$

where N = strokes per minute of the polished rod

R = ratio T/T_1

T = period of the natural vibration, sec.

The vertical scale is the right-hand part of the basic formula 1, with d_2 replaced by 1. In other words, this scale is in multiples of the polished-rod stroke.

It will be noted that the graph consists of a family of curves, each one corresponding to a different value of the damping factor u . The top curve represents the stroke of the plunger for zero damping. Each of these curves is divided into two parts at approximately the ratio T/T_1 equals 1, which is the point of resonance or the point of maximum vibration in our rubber-band experiment. With zero damping, the plunger stroke is infinite here, and greater damping tends to reduce the magnitude of the plunger stroke at resonance, and move the point of resonance to a slightly lower speed or ratio of T/T_1 .

The polished-rod strokes per minute, at the point of resonance, depend upon the period of the natural vibration T . For many of the Wilcox sand wells of the South Oklahoma City field, the value of T was found to be about 2.0 sec., with bottom-hole conditions as they were in the fall of 1935, which placed resonance at about 30 strokes per minute, irrespective of the length of the polished-rod stroke. Many of the water wells in the Wilcox sand in the Seminole area have a value of T equal to 1.5 sec., making the point of resonance 40 strokes per minute. Lighter and shallower wells might have a value of T equal to 1.0 sec., with resonance occurring at 60 strokes per minute. Again, heavier and deeper wells might have a value of T equal to 2.5 sec., which would place resonance at 24 strokes per minute. These speeds would be reduced in proportion for operation at a ratio of T/T_1 less than unity; for instance the speeds would be just half for operation at a ratio of 0.5.

At speeds higher than those of resonance, or at ratios of T/T_1 greater than unity, the stroke of the plunger becomes smaller and smaller, approaching zero as a limit. This again coincides with our observations of the reaction of the weight on the chain of rubber bands. At speeds slower than those at resonance, or at ratios of T/T_1 less than unity, the curves of Fig. 1 show that the plunger stroke becomes shorter and shorter, approaching the stroke of the polished rod as a limit. This checks with the experiment with the rubber bands. However, the reaction of the plunger of the sucker-rod pump does not conform at the lower speeds, as will be pointed out in more detail later.

DEDUCTIONS

All the wells that the authors have had an opportunity to check have been operated at a speed that makes the ratio of the periods of the two vibrations less than unity. In other words, the pumps are operated below resonance, and observations have led to the belief that many wells with a poor rod record are operated at a speed that gives too high a ratio of T/T_1 . This leads to the first generalization, that from the point of view of the duty on the sucker rods there is a definite ratio of T/T_1 , which should not be exceeded. The exact location of this critical ratio must be determined more exactly, by additional field work, correlating rod performance with well measurements. However, the authors will hazard a guess that it will be found close to 0.5. On large wells, where the required production necessitates the use of the longer polished-rod strokes, better results will probably be secured by operating at 0.4. On small wells, where shorter strokes can be used to advantage, it will probably prove practical to operate at T/T_1 equal to 0.6.

That such a maximum ratio of T/T_1 exists is entirely consistent with the fundamental theory, and with operating and experimental experience. The stresses that cause the majority of sucker-rod failures are vibratory in character. The pumping mechanism does not displace the string of rods bodily, as it would if the string were a rigid body, but sets up a vibration, which is transmitted to the lower end. At the same time, the string of rods is set to vibrating with a natural frequency, and this wave motion is added to that of the pumping mechanism to produce the motion of the plunger. These vibratory stresses are relatively intense at the plunger, are damped out, and become relatively feeble at the polished rod. However, they are superimposed upon the dead weight stress, which is a maximum at the polished rod and a minimum at the plunger. Therefore, it is possible for these two to add together, at some point in the length of the string of rods, to produce a stress that is greater than the stress in the top sucker rod. This is the most likely explanation of the frequent breaks in the body of the string.

These vibratory stresses may be intensified by various causes. First, there is the possibility of a phase difference between the plunger and the polished rod. We are again indebted to Dr. Timoshenko for the following formula, which enables us to compute approximately this phase relationship:

$$\tan a = \frac{uTT_1}{T_1^2 - T^2} \quad [3]$$

where a = angle

u = damping factor

T = period of natural vibration, sec.

T_1 = period of forced vibration, sec.

This shows that at very low speeds the polished rod and plunger are approximately in phase. At resonance, they are 90° out of phase, and above resonance they approach a phase difference of 180° . In this latter case, the plunger would be coming up while the polished rod was going down. It is impossible to demonstrate this in the field, because the sucker rods would not stand the strain of operation at these higher speeds, and no practical means has been developed to actually measure this phase difference in the well. It can be observed, however, in the laboratory, with a more refined model of a walking beam, a chain of rubber bands and a weight in the form of a bucket, so that the mass can be varied by adding or removing bird shot. Any ratio of T/T_1 can be obtained quite easily, by varying the mass in this way.

It is quite possible that this phase difference increases the sucker-rod stress, without doing any useful work. In fact, many investigators ascribe the peak of the dynamometer card to a phase difference. However, such a peak would be caused if the natural vibration apposed the motion of the polished rod at that point, and such a theory supplies a logical explanation of the loops and hooks at the ends of the cards. Also, this theory is supported by the fact that the cards made by a fluid motor, operated by compressed air or gas, so that the velocity of the polished rod varies inversely with the load, do not show this characteristic peak. Irrespective of the difference in phase, this peak represents an undesirable stressing of the sucker rods, and its intensity will be reduced as the ratio T/T_1 is reduced.

It is entirely possible to get 100 per cent overstroke, at a ratio of 0.8 in an oil well with a moderate amount of gas, and no water. Such an overstroke is in the form of a compressor or longitudinal wave, with a definite wave length, and it would cause an additional stress in proportion to the force required to stretch the rods that much. The spring constant of the $\frac{7}{8}$ and $\frac{3}{4}$ -in. rod strings, used with $1\frac{3}{4}$ -in. plungers, in many of the Oklahoma City wells is 191 lb. per inch. Therefore, with a 72-in. polished-rod stroke, this stress might be of the magnitude of 72×191 or 13,752 lb. This example is illustrative, as it would prove impractical to operate a 72-in. stroke, under such conditions. In order to get the desired displacement, it would be necessary to use a longer stroke, at fewer strokes per minute, which would automatically reduce the ratio T/T_1 .

Again, it is well established that the addition of two periodic motions, even if they are sinusoidal, may result in a periodic motion, which is not sinusoidal. Close to resonance, this produces the phenomenon of beats. Elsewhere, the resultant motion describes a definite but irregular course, varying in amplitude from the sum to the difference of the two amplitudes as shown in Fig. 2. It is not difficult to imagine that such a reaction will subject the string of rods to intense stresses of such short

duration that our dynamometers are insensitive to them. Here, the remedy is operation at a lower ratio of T/T_1 to lessen their intensity and possibly give a more satisfactory pattern to the resultant motion. Whatever shocks remain make the use of a shock-absorber element desirable.

It has not been established that this periodicity can exist under all conditions, but it has been established that it does exist under certain conditions. When a dynamometer card is retraced a number of times, the upstroke and downstroke lines do not coincide. Also, we have motion pictures of the polished-rod grip of a Sullivan pumphead, operating on a Simpson sand well in Oklahoma City, which, when run at slow speed,

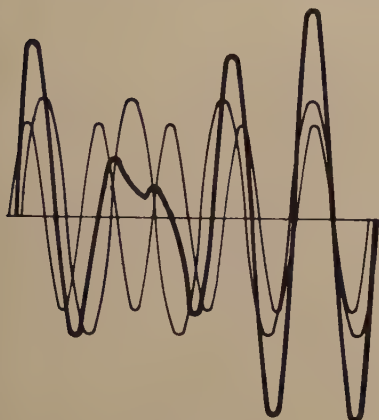


FIG. 2.

FIG. 2.—DIAGRAM OF POSSIBLE PATH OF PLUNGER WHERE RATIO T/T_1 EQUALS 0.8.

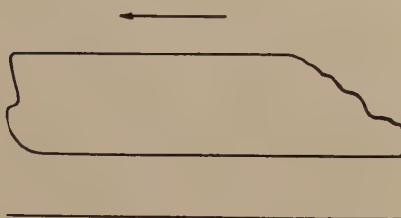


FIG. 3.

FIG. 3.—POLISHED ROD RETURNED TO TOP OF STROKE BEFORE COMPLETING DOWNSTROKE.

show the polished-rod stopping, after making about 20 per cent of the downstroke. It then returns to the top of the stroke before reversing and completing the downstroke. That such reactions are observable in the pumphead is due to the fact that both ends of the string of sucker rods are free, and can adjust themselves to varying load conditions. An indicator card of a Sullivan pumphead, taken under such conditions, is shown as Fig. 3.

On the practical side, the history of the Oklahoma City wells seems to confirm this general deduction. Low bottom-hole pressures were common when this field went on the pump, as the gas-lifting stage was prolonged. Wells with moderately high bottom-hole pressures and approximately the same characteristics as to rod strings, plunger diameter, fluid and submergence, were pumped successfully at 18 or more strokes per minute. As the fluid levels have declined, many of the operators have obtained better performance at slower speeds and 15 strokes per minute are not uncommon. In many cases, the necessity

for slower speeds has been counteracted by the substitution of $1\frac{1}{4}$ -in. plungers, or strings of larger rods. As the wells approach the stripper stage, the small production available makes a shorter polished-rod stroke practical, and also reduces the breakage resulting from the plunger sanding up and sticking, and the vibratory stresses, under these conditions, are not serious. However, the long stroke is practical, when the fluid type motor is used under stripper conditions, as the motor will stop, before it will subject the rods to a stress sufficient to break them. All of which is a demonstration of the practical benefit of operating a well at a suitable ratio of the period of the natural vibration to the period of the forced vibration.

Some additional comment on the specific factors of formula 1 may prove helpful. There are three unknowns; the stroke of the plunger, the period of the natural vibration, and the damping factor. The stroke of the plunger can be measured with considerable accuracy, with a Sargent dynamometer; however, there is no very accurate way to determine the period of the natural vibration or the damping factor. In experimental work, therefore, it is necessary to compute the period of the natural vibration, from estimated data, and then it is possible to solve for the damping factor. While this introduces a considerable error, at times, the relative error is small and the results are of considerable value.

In the formula, d_2 is the amplitude of the forced vibration, and is half the stroke of the polished rod. The same is true with d_3 , which is the amplitude of the resultant vibration, or half the plunger stroke. However, it has been found sufficiently accurate, for our purposes, to consider these as the stroke of the polished rod and the stroke of the plunger, respectively. The period of the forced or pumping mechanism vibration, T_1 , gives no trouble, as it is equal to 60 divided by the strokes per minute.

The period of the natural vibration T is a more difficult problem. It can be computed from the expression

$$T = 6.28\sqrt{\frac{d_s}{g}} \quad [4]$$

where T = period of natural vibration, sec.

d_s = static stretch, in feet, caused by the weight of the fluid and one-third the weight of the rods.

g = acceleration due to gravity, ft. per sec. squared.

This is solved, more conveniently, on a slide rule, if simplified to

$$T = 0.3195\sqrt{d_s} \quad [4a]$$

where d_s = static stretch in inches, caused by the weight of the fluid and one-third the weight of the rods.

This static elongation is computed from Hooke's Law:

$$e = \frac{PL}{AE} \quad [5]$$

where e = elongation, in.

P = force producing stretch, lb.

L = length of spring, in.

A = area, sq. in.

E = modulus of elasticity.

In the absence of specific information in regard to the value of this modulus for different sucker rods, a uniform value of 30,000,000 has been used.

It will be found convenient, in many instances, to determine the spring constant, or the force required to stretch the spring one inch, first, and then compute the total stretch by dividing the load by this constant. This constant is computed by making e equal to 1, in formula 5, and solving for P , which then becomes the spring constant k . This is all that is required for a straight string of rods, but for a tapered string consisting of two different sizes of rods, the constant for each length of each size must be computed separately in this manner, becoming k_1 and k_2 . Then the spring constant for the string is:

$$k = \frac{k_1 k_2}{k_1 + k_2} \quad [6]$$

Similarly, the constant for a three-rod string is:

$$k = \frac{k_1 k_2 k_3}{k_1 k_2 + k_1 k_3 + k_2 k_3} \quad [6a]$$

The weight causing this stretch, d_s in formula 4, is the sum of the weight of the fluid and one-third the weight of the rods. The weight of the fluid depends on the pumping lift and the density of the fluid in the tubing. These are factors that cannot be determined easily, and therefore stand in the way of accurate quantitative results. However, it would require a considerable drop in fluid level to affect the results seriously, so this factor can generally be estimated sufficiently closely for our purposes. It should be noted that the lower the fluid level, the greater will be the period of the natural vibration. As the polished-rod velocity increases, the density of the fluid in the tubing decreases, reaching a minimum at the higher velocities. This would make the period of the natural vibration smaller, but in practice the loss in density seems to be offset by a drop in fluid level, or some other factor, which, in the light of our present limited knowledge, seems to keep the period of

the natural vibration constant, throughout the practical range in polished-rod velocities. However, it will be well to keep in mind that we may discover, eventually, that there are conditions that make the period of the natural vibration different at different pumping speeds in the same well.

The weight of the rods in the fluid can be determined with a fair degree of accuracy, and further comment seems unnecessary. In problems of this kind, however, where the weight of the spring is so great in relation to the weight of the fluid, it is necessary to consider the weight of the spring in computing the period of the natural vibration. A useful approximation is to add one-third the weight of the spring or rods, to the weight of the fluid, a result that follows from integrating a differential containing an energy factor.

It should be clear, now, that one of the objectives in selecting sucker-rod pumping equipment is to choose the component parts to give as small a period T of the natural vibration as is compatible with the practical advantage to be gained. Sometimes, this can be accomplished by substituting larger rods or a smaller plunger for those which would be used normally. Basing the opinion on a limited knowledge of Oklahoma City conditions, oversized rods rarely permit an increase in pumping speed of more than one stroke per minute. Under these same conditions, reducing the size of the plunger from $1\frac{3}{4}$ to $1\frac{1}{4}$ in., or about half, will permit an increase in pumping speed of about 2.5 strokes per minute. Both of these expedients have distinct fields of usefulness, particularly where relatively little production is required. Where large capacity is required, to handle water or to take potentials, the vibratory stresses cannot be controlled in this way, and it becomes necessary to use a polished-rod stroke of a length established by well conditions. This phase of the problem will be enlarged upon later.

DAMPING FACTOR

Only the damping factor remains for consideration before we can give some thought to the practical aspects of this analysis. As has been pointed out, part of the damping effect is due to hysteresis in the sucker rods themselves, but this is small compared to the damping effect of the fluid friction in the tubing. Investigators in other fields have discovered that this is proportional to the velocity at the lower speeds and is proportional to some power of the velocity at the higher speeds. This power is generally taken as the square. When the authors first became interested in this problem, they concluded that the velocities involved were low enough to make the damping factor directly proportional to the velocity, and therefore of relatively little importance. This has since proved to be an error—and the damping factor is as important as

any involved and is responsible for the limitation of the production of the sucker-rod pump, when the percentage of water is high.

It is obvious that the damping factor has some direct relationship to the density, possibly more correctly, the viscosity of the fluid in the tubing. We can easily isolate three conditions: (1) no fluid in the tubing, which is the case in a low fluid level well, when pumping up; (2) various densities of crude oil, with varying amounts of gas and (3) various mixtures of oil and water with varying quantities of gas. In the first case, the absence of fluid load should reduce the length of the plunger stroke. However, the Sargent dynamometer shows maximum stroke, uniformly, under these conditions, with the plunger often bumping up and down. This indicates that the damping factor is negligible when the tubing is full of gas, and suggests the desirability of slow speed when pumping up. This condition does not last long, as the tubing is soon filled with some kind of fluid. Our knowledge of the range of the damping factor under varying fluid conditions is as yet incomplete and our measurements may prove none too accurate. However, with the best technique available, we have plotted a range from about 0.3 for crude oil with considerable gas to possibly better than 2.5 for a well producing mostly water with but a small amount of gas. Also, it is fairly well established that the quantity of gas present determines the size of the damping factor. This wide range was entirely unexpected and has an important effect on the performance of the sucker-rod pump.

The question will arise, naturally, as to what can be done to counteract the effect of the damping factor when it is undesirably high. One remedy is rather definitely established—lower the ratio T/T_1 of the period of the natural vibration to the period of the forced vibration. Another possible remedy has not been so definitely established. As the high damping factor is a velocity reaction, it is possible that the use of oversize tubing may lower it. This opens up an interesting field for investigation, but generalization is impossible at the present. Before leaving this subject, it should be pointed out that it is possible that the damping factor changes with the velocity.

Those who have come with the authors this far may well ask what objection there is to a high damping factor? The answer, based on theoretical considerations, is to be found in that portion of the characteristic curve of Fig. 1 which lies below resonance. This shows clearly that as the damping factor increases the plunger understrokes rather than overstrokes. This results in a reduction in displacement; that is, production at the time production is needed most.

PRACTICAL APPLICATIONS

This appears to be the case in actual practice, and the significance will be apparent from an examination of Fig. 4, which is a composite

graph interpolated from our field tests. It is based on a well with the physical characteristics of many of the Wilcox sand wells in Oklahoma City, and compares the resultant plunger strokes of 120-in. and 60-in. polished-rod strokes. The horizontal scale is the average polished-rod velocity, and supplementary scales for strokes per minute and the ratio of T/T_1 , are shown. Future tests will increase our knowledge of the range of conditions which produce these results, but there is little doubt now of the accuracy of their broad significance.

The upper curve of each group represents the length of the plunger stroke for a damping factor of 0.6, while the lower curves represent the length of the plunger stroke for a damping factor of 1.8. The upper curve is probably typical of the average oil well, with no water and a

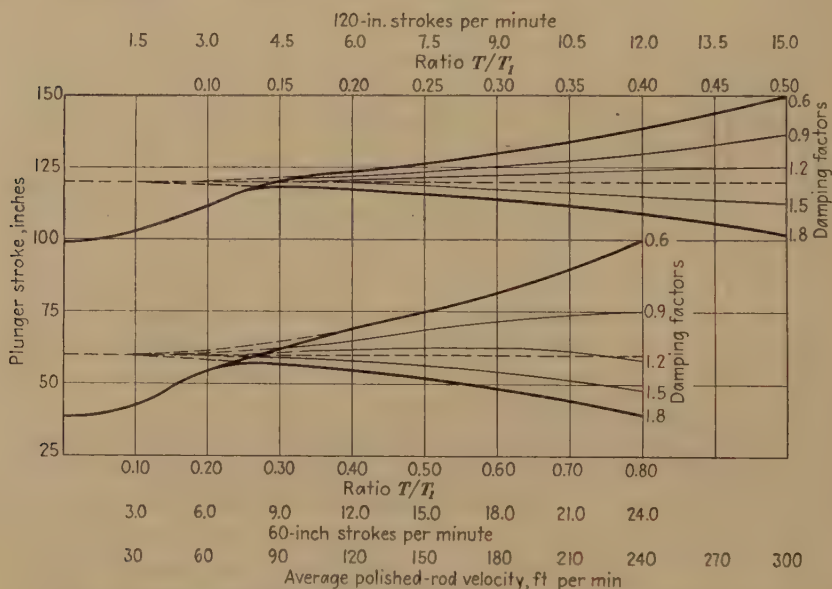


FIG. 4.—EFFECT ON PLUNGER STROKE OF DAMPING FACTOR AND T/T_1 .

moderate amount of gas. The lower curve is probably typical of relatively heavy water wells, say 60 per cent water and a moderate amount of gas. Varying conditions will give curves above, below or between these limits, but it is believed that the great majority of wells will be found to fall on or between these limits. It will be noted that both the 120-in. and 60-in. polished-rod strokes have a ratio of T/T_1 equal to a half when operated at 15 strokes per minute. With a damping factor of 1.8 the computed plunger velocity is 255 ft. per minute for the long stroke, against 127.5 ft. per minute for the short stroke. While this is an extreme case used for illustrative purposes, it demonstrates that a high damping factor results in an appreciable loss in production and shows

that the longer polished-rod strokes are a practical means for recovering part of this loss.

With a damping factor of 0.6 the computed plunger velocity is 371 ft. per minute, for the long stroke, against 186 ft. per minute for the short stroke. With a sacrifice of rod performance, this difference could be reduced by speeding up the short stroke. However, speeding up the short stroke with a high damping factor would increase the difference. That these general effects of the damping factor and polished-rod stroke are correct is well established in spite of the results of several tests, which credit the short stroke with the greater production when pumping oil with no water. Such comparisons have been made with the polished-rod

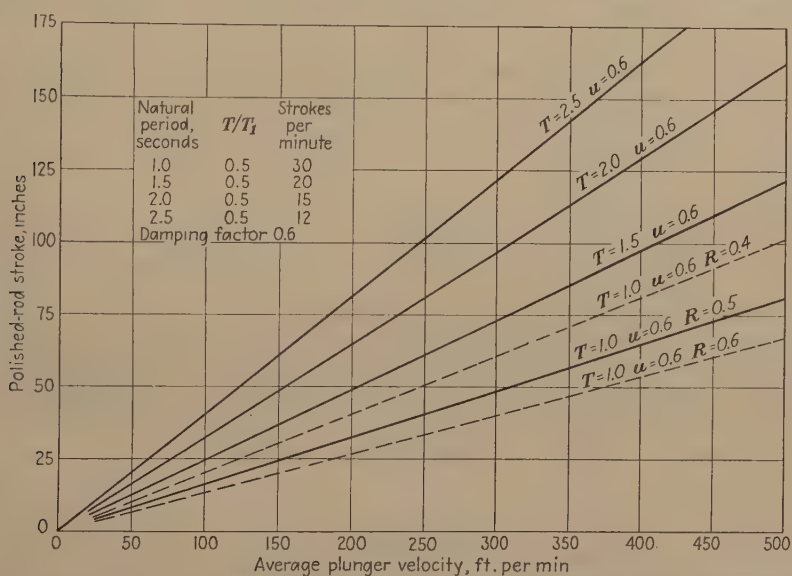


FIG. 5.—LENGTH OF POLISHED-ROD STROKE FOR REQUIRED PLUNGER DISPLACEMENT.

velocities nearly equal, and what has been said above indicates that the production of the short stroke would be the greater, but the sucker-rod performance would be bad. This is not the proper basis for comparison, as the true function of the long stroke is to make it possible to increase the average velocity without increasing the vibratory stresses materially. Such comparisons should be made with the ratios of T/T_1 approximately equal, then the long stroke will give the greater production, with a better rod performance.

Fig. 4 shows the zone at the lower speeds in which the sucker-rod pump vibrates as a system with variable mass, and where the mathematics does not apply. The curve of the length of the plunger stroke may be regarded as two curves, tangent to each other at a velocity where the kinetic energy of the rods equals the potential energy of the

fluid in the tubing. This point of tangency, therefore, depends on the density of the fluid in the tubing and the pumping lift and will be different for different wells. This zone occurs at such low speeds that the vibratory stresses are not a factor and the divergence from the general theory, therefore, is of no practical importance.

Throughout this discussion, we have endeavored to make clear the importance of the ratio T/T_1 of the period of the natural vibration to the period of the forced or pumping mechanism vibration, to the problem of limiting the duty on the sucker rods as much as possible to the component that does the useful work. There is a definite ratio, probably 0.5, which should not be exceeded if the rods are to give satisfactory service. This leads to the problem of getting plunger displacement and still maintaining a satisfactory ratio. It has been pointed out that over-size rods help moderately and reducing the plunger about a half helps more and can be used to advantage when large production is not required. However, where large production is required, we must resort to the longer polished-rod stroke. An illustrative example will make the practical application clear.

Assume a fluid with a specific gravity of 1.0. The static stress in the top rod will be about 25,000 lb. per sq. in., if we assume zero submergence and set a $1\frac{3}{4}$ -in. plunger at 3750 ft. on a straight string of $\frac{5}{8}$ -in. sucker rods. This unit stress will vary, of course, with the type of rods and the type of pumping unit, but in general it is best to start with the largest plunger that can be run to the required depth, as this tends to keep the strokes per minute to a minimum. The weight of the rods in the fluid is 3900 lb., and the spring constant k is found to be 205 lb. per in., using formula 5. In the usual manner, using the total area of the plunger, the weight of the fluid is computed to be 4290 lb. Adding one-third the weight of the rods to the weight of the fluid and dividing by the spring constant, gives us a static stretch of 27.3 in. The natural period of the rods is found to be 1.67 sec. by substituting in formula 4a. The maximum strokes per minute for a ratio of T/T_1 equal to 0.5, is found from formula 2 to be 18.0.

The length of stroke required to give the desired production is found by substituting in:

$$S = \frac{Q}{cN} \quad [7]$$

where S = length of plunger stroke, in.

Q = plunger displacement, bbl. per day.

N = strokes per minute, corresponding to the assumed ratio T/T_1 , taken as 0.5.

c = plunger constant:

PLUNGER, IN.	CONSTANT	PLUNGER, IN.	CONSTANT
1	0.117	2 $\frac{1}{8}$	0.526
1 $\frac{1}{8}$	0.148	2 $\frac{1}{4}$	0.590
1 $\frac{1}{4}$	0.182	2 $\frac{3}{8}$	0.657
1 $\frac{3}{8}$	0.222	2 $\frac{1}{2}$	0.728
1 $\frac{1}{2}$	0.262	2 $\frac{3}{4}$	0.882
1 $\frac{5}{8}$	0.308	3 $\frac{1}{4}$	1.638
1 $\frac{3}{4}$	0.357	4 $\frac{1}{4}$	2.630
2	0.466		

From this, we find that the plunger stroke should be 78 in. for a production of 500 bbl. per day; 156 in. for a production of 1000 bbl. per day and 234 in. for a production of 1500 bbl. per day. This is shown graphically in Fig. 5.

The stroke of the polished rod can be found by estimating the damping factor and dividing the plunger stroke by the proper factor taken from Table 1. Thus, the polished-rod stroke would be $78/1.24$, or 63 in. for a damping factor of 0.6 and it would be $78/0.85$ or 92 in. for a damping factor of 1.8. In order to complete the proposition, these polished-rod strokes should be divided by the estimated apparent volumetric efficiency. Obviously, this new method of designing the sucker-rod pump is handicapped, as is the older method, by the lack of accurate advance information in regard to the physical characteristics of the well. However, we can be sure of the worst conditions if we assume zero submergence and salt water. Then an effective bracket of the problem can be obtained if the computations are repeated for different submergences, such as 30 per cent, 45 per cent and 60 per cent. This new method promises to give more definite results, and as our experience with it grows, it may supplant the older approximation based on impulse factors.

ACKNOWLEDGMENTS

Grateful acknowledgment is made to S. B. Sargent, Jr., and his associates of the Sargent Engineering Corporation, whose bottom-hole dynamometer has greatly improved the technique of investigating the reaction of the plunger.

The generosity of the Carter Oil Co., the Eason Oil Co., the Pure Oil Co. and the Texas Company, and the earnest cooperation of the individuals associated with these companies too numerous to mention by name, in permitting the authors to test their wells, is largely responsible for such progress as has been made.

REFERENCES

There are a number of good books on the general subject of elasticity and vibrations, but the following are especially useful in studying the sucker-rod pump:

S. Timoshenko and J. M. Lessells: Applied Elasticity. Westinghouse Technical Night School Press.

J. P. Den Hartog: Mechanical Vibrations. McGraw-Hill Book Co., Inc.

Determination of Fluid Level in Oil Wells by the Pressure-wave Echo Method

BY C. P. WALKER*

(Los Angeles Meeting, October, 1936)

DETERMINING the distance to remote objects by observing the time required for sound to traverse the intervening space is an old practice. Attempts have been made to use this method for determining the fluid level in oil wells but as far as the writer is aware it was not found to be practicable, because vibrations in gas in the audible frequency range do not travel as well and as far as low-frequency pressure waves, which are capable of transmitting a greater amount of energy than can be transmitted by audible waves. Wood, in his book "Sound," states that in a given medium the range of sound transmission will vary inversely as the square of the frequency. The fact that the sound from a whistle having a low tone has a much lower attenuation rate than that from a whistle of high pitch is well known. Also, the pressure waves caused by cannon fire often rattle windows at points so distant that no sound of the cannon is heard.

In 1932 P. E. Lehr and H. T. Wyatt, of the Shell Oil Co., experimented with the principle of the concussion, or pressure-wave echo, method of determining fluid levels in oil wells. They released compressed gas into the top of the casing, thereby creating a pressure wave, which traveled down the well and back again. Their experiments proved conclusively that, with the proper apparatus for recording the echoes and determining the velocities at which the waves travel, the method could be used successfully for determining fluid levels in oil wells.

Wells are often equipped with from one to three tubing catchers and these together with the top of the liner are frequently above the fluid. Each of these obstructions reflects a part of the pressure wave. In such wells there may be, therefore, as many as five pressure-wave reflections. Thus it is obvious that in order to identify the various reflections and to determine therefrom the fluid level in a well it is necessary to obtain a graphic record of these reflections.

Manuscript received at the office of the Institute Oct. 31, 1936; revised April 14, 1937.

* The Depthograph Co., San Marino, Calif.

DEVELOPMENT OF DEPTHOGRAPH

In 1935 the writer began the development of suitable instruments and apparatus for making use of the pressure-wave method of determining fluid levels in oil wells on a commercial basis.

For the preliminary studies an electric oscillograph was used with a microphone for receiving the wave reflections. Commercial microphones proved to be entirely unsuited to the needs, as the frequency of the

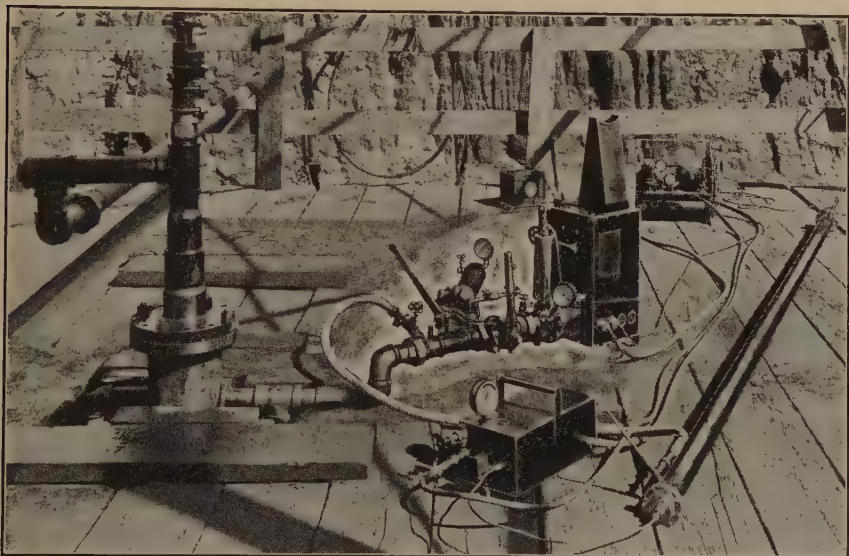


FIG. 1.—DEPTHOGRAPH, INCLUDING APPARATUS FOR MEASURING PRESSURE-WAVE VELOCITY IN GAS FLOWING FROM WELL.

pressure wave was on the order of about three cycles per second. These microphones were too sensitive to the audible and other high-frequency sounds and not sufficiently sensitive to the low-frequency pressure wave. Consequently the high-frequency, or audible sounds, produced by sucker rods and by the hiss of gas through valves and leaks obscured the wave reflections from the fluid level and other obstructions of which the depths were to be determined.

As there was not available a microphone with sufficiently low frequency response to receive these pressure-wave reflections a mechanical receiver was designed and built. This receiver consists of a diaphragm, one side of which is exposed to the well-casing space through a 2-in. tube. The space behind the diaphragm is also connected into the casing for the purpose of equalizing the casing static pressure on both sides of the diaphragm. The present design of the Depthograph receiver (Figs. 1 and 2) is capable of operation with casing pressures up to 500 lb. per square inch.

The diaphragm actuates a small mirror. A light beam directed against the mirror is reflected into an optical system where its movement is amplified and a part of it is directed onto a ground glass for observation and another part of it is projected onto a strip of moving sensitized paper and photographed. The sensitized paper is usually run at the rate of about 2 in. per second, making a record chart 20 in. long for a well where the fluid is 5000 ft. from the top. Each inch on the chart represents approximately 250 ft. of depth in the well. This large-scale chart (Fig. 3) makes it easy to read off the depth accurately. The chart speed may be varied from 1 to 5 in. per second, at will.

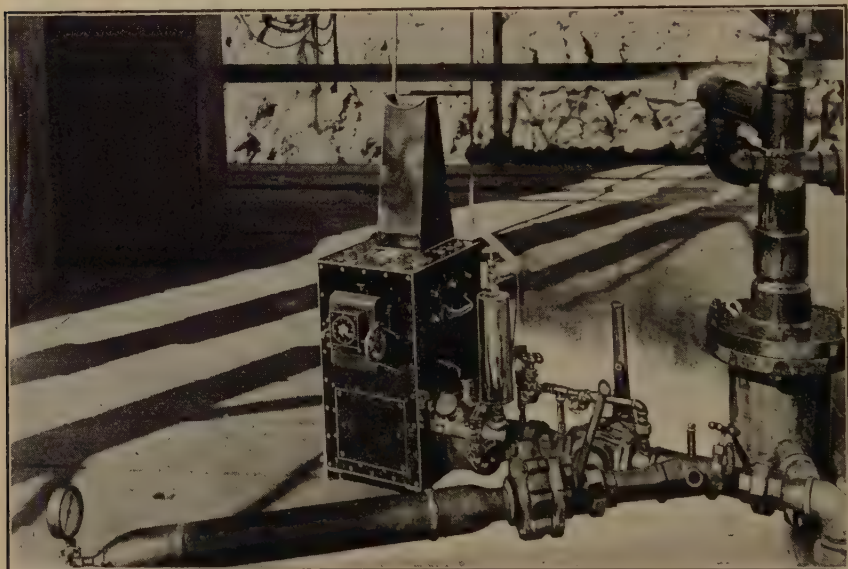


FIG. 2.—DEPTHOGRAPH RECEIVER AND RECORDER.

A timer controlled by a tuning fork and driven by a synchronous motor puts a series of time marks along one edge of the record chart—one mark for every 0.1 sec. At the end of every second the time mark is about twice as large as the intervening 0.1-sec. marks, which makes it possible to quickly determine the time intervals to the various echoes.

The body of the truck for transporting the instruments and equipment is made light-tight and is equipped with facilities for developing and fixing the record charts. In about eight minutes after completing a fluid-level test the chart can be developed and made ready for inspection.

OPERATION OF INSTRUMENT

At the moment of releasing the compressed gas into the casing to produce the pressure wave the recording apparatus is connected to the casing through a small needle valve, for the purpose of obtaining a

record of the start of the pressure wave from the top of the well. A moment after the gas is released into the casing the main valve connecting the instrument diaphragm chamber to the casing is opened, making the instrument sensitive for receiving the reflected pressure waves.

The velocity at which the pressure wave travels in the well is the same as the velocity at which sound waves would travel. It varies from about 850 to over 1400 ft. per second in the various wells and depends upon the composition of gas contained in the well.

Many wells have a tubing catcher above the fluid level and the distance down to it is usually known. Catchers reflect a part of the wave and are easily located on the Depthograph charts, as shown by Fig. 3. This provides an easy means of accurately determining the wave velocity in the well.

Where there is not an obstruction such as a catcher at a known location, or a liner top in the well, to reflect back a wave, it is necessary to determine the velocity at which the pressure wave travels in the well under test in order to determine the fluid level. As it has been found to be impossible to calculate this velocity from the physical properties of a sample of the well gas secured at the surface, a search of considerable literature on the subject was made in an effort to find a suitable method of measuring it, but no accurate method suitable for field use could be found. It was then decided that velocity-measuring apparatus should be developed making use of a low-frequency wave. The apparatus designed and built for these velocity measurements (Fig. 1) consists of a tube about 2 in. in diameter and 12 ft. long, through which gas flows from the well under test, a device for creating and maintaining a pressure-wave oscillation in the tube and an instrument for detecting the existence of perfect resonance in the tube.

If one's hand is clapped over the open end of a tube that is closed at the opposite end, and the tube is not too short, the wave thus created can be felt as it oscillates from one end to the other of the tube. The first idea considered was to photograph such an oscillating wave, which would rapidly die out in the tube, and from the photograph determine the frequency of oscillations. From this known frequency and the known length of the tube the rate of

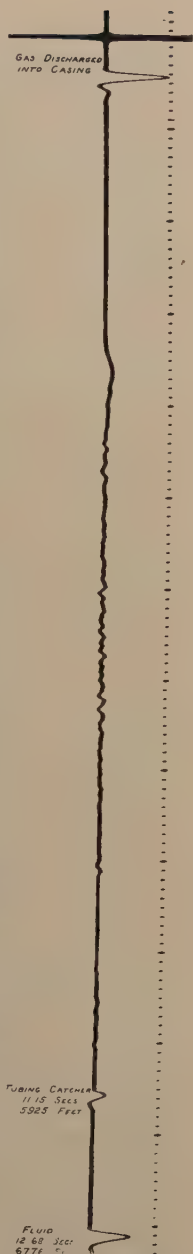


FIG. 3.—DEPTHOGRAPH CHART.

Well depth 7921 ft.; pump set at 7623 ft.

wave travel in the tube could be determined. This method was considered to be too long and tedious and not sufficiently accurate, so it was decided to maintain the oscillations in the tube either electrically or mechanically and obtain a longer photographic record of the oscillations in the tube, thus making the process more accurate. The next step along this line of reasoning was to maintain the oscillations at the rate at which they would naturally oscillate without outside interference; that is, produce resonance in the tube by electrical or mechanical means and provide a means of determining the rate of application of the impulses that maintained the resonance. This requirement was not difficult to meet and in the present form of the instrument the impulses are applied to the tube pneumatically by means of a valve driven by an adjustable speed motor. A revolution recorder attached to the motor shaft provides the means of determining the frequency of oscillations in the tube.

Air is used as the basis for all gas-velocity measurements. The frequency at which resonance occurs with gas in the tube is compared directly with the resonant frequency with air in the tube. Knowing the velocity at which the pressure wave will travel in air the velocity in the tube with gas flowing through it is directly proportional to the resonant frequency. For example, if the resonant frequency with gas in the tube is 10 per cent higher than it is with air in it the velocity of the wave in the gas is 10 per cent faster than it is in air.

To indicate the condition of perfect resonance in the tube, one end of it is attached to the same diaphragm-operated mirror system that is used for indicating and photographing the pressure-wave echoes from the well. The light beam from the mirror is directed upon a revolving mirror with eight reflecting faces. The oscillations of the pressure wave in the calibrating tube cause the light beam to vibrate parallel to the axis of the revolving mirror. When the mirror is rotated the light beam is moved at right angles to the movement imparted to it by the oscillations in the tube. This resultant motion of the beam is observed upon a ground glass and represents the form of the wave that is oscillating in the tube. When the condition of perfect resonance occurs in the tube the amplitude of this wave reaches a maximum and its shape is quite critical. If the frequency of applying the impulses to the tube is varied slightly from the natural period of the tube the wave as seen upon the ground glass undergoes a radical change in shape and its amplitude is diminished.

As the intensity of oscillations in the tube is a maximum when perfect resonance occurs in it, a device for indicating the intensity of the pressure wave oscillating in the tube makes a simple means for determining when the rate of application of the impulses to the tube is such that the tube is in resonance. For indicating resonance by this method a

microphone is attached to one end of the tube, where it can pick up the wave oscillations and pass them on to an amplifier. The amplifier output meter gives an accurate indication of resonance in the tube. The tuning is very sharp and the rate of application of impulses to the tube can be very accurately adjusted to keep it at the exact resonance point by watching the output meter and keeping this rate such as to produce a maximum output as indicated by the meter. This electrical method, because of its simplicity, has replaced the revolving-mirror method for determining the frequency and velocity of the wave in the calibrating tube.

However, the determination of the pressure-wave velocity in the wells from tubing catchers or reflectors installed in the well above the fluid level is more accurate than the indirect method of measuring the velocity in the calibrating apparatus and it is recommended that this method be used where the fluid level is low and a high degree of accuracy is required. Some oil companies are now making it a practice to install a wave reflector in the well above the static fluid level the first time the tubing is pulled, thus providing a permanent yardstick in the well by means of which the fluid level can be accurately determined by the Depthograph at any time during the life of the well.

DETERMINATIONS

The velocity of the pressure wave, V , increases slightly with an increase in temperature. This increase is proportional to the square

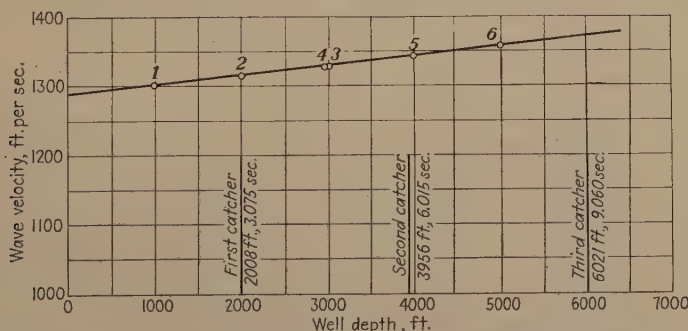


FIG. 4.—VELOCITY-DEPTH CURVE MADE FROM TESTS IN WELL IN VENTURA FIELD.
Gas gravity, 0.72; casing pressure, 315 lb. per square inch.

Velocities: 1, top to first catcher; 2, top to second catcher; 3, top to third catcher; 4, first to second catcher; 5, first to third catcher; 6, second to third catcher.

root of the absolute temperature T , or $\frac{V_1}{V_2} = \sqrt{\frac{T_1}{T_2}}$. Fig. 4 is drawn from an actual test in a well and shows how the velocity increases with well depth and temperature. This well had three tubing catchers in it, providing three markers in the well from which the variation in wave velocity with depth could be determined.

Several wells with a wide variation in gas gravity and quantity of gas and containing two or more wave reflectors from which the wave velocity at different depths in the wells could be determined have been tested and in all of them the velocity-depth gradient has been found to be constant for the full depth of the wells.

If the reflector is not too far above the fluid in the well, the fluid level can be determined accurately by using the mean wave velocity to the catcher. If the fluid is very far below the catcher the mean velocity to it, owing to the higher temperature, will be slightly greater than that to the catcher, in which case it will be necessary to make a slight correction in the velocity to the catcher before using it to determine the distance to the fluid.

By observing the echoes on the ground glass of the Depthograph when fluid-level tests are being made, the operator is able to determine the approximate distance from the reflector to the fluid. If the distance is too far to determine the fluid level from the catcher reflection by straight proportion, the temperature of the gas flowing from the well is measured. Having this temperature and knowing the average bottom-hole temperature for the field in which the well is located, the slope of the velocity-depth curve for the well can be determined.

Knowing the gas temperature at the top and the estimated temperatures at the reflector and the fluid surface, and the average velocity to the reflector, as determined from the Depthograph chart, the average velocity to the fluid is

$$V_{mf} = V_{mr} \sqrt{\frac{460 + T_{mf_t}}{460 + T_{mr}}}$$

where V_{mf} = mean velocity to the fluid,

V_{mr} = mean velocity to the reflector,

T_{mf_t} = mean temperature to the fluid, deg. F.,

T_{mr} = mean temperature to the reflector, deg. F.

The mean velocity to the fluid thus determined multiplied by the seconds to the fluid as shown on the Depthograph chart will give the distance to the fluid. As the velocity correction for temperature is very small, an error in the assumed bottom-hole temperature will result in a negligible error in the fluid-level determination.

It is also true that correction factors derived from the above equation will lie on a slightly curved line. However, the radius of curvature is very large and this method of correcting the velocity has been found to produce results that are well within the limits of accuracy required.

Up to the present time the pressure-wave velocity in most of the wells tested has been determined from catchers, reflectors and liner tops. A method is now being developed by means of which the number of joints of tubing above the surface of the fluid can be determined. Practi-

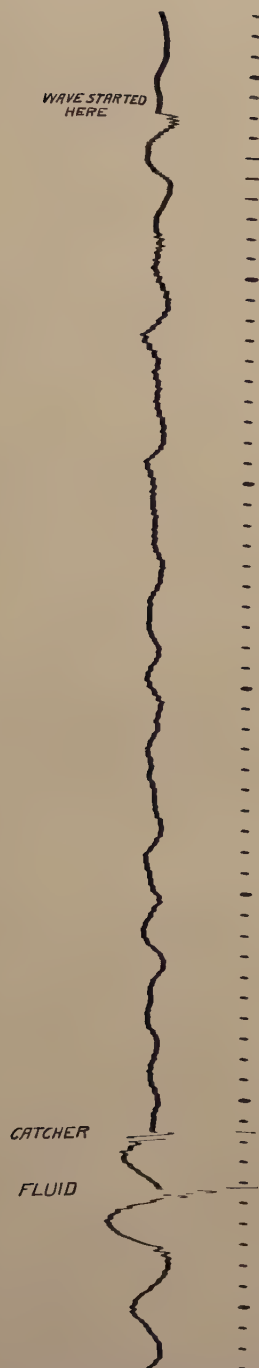


FIG. 5.—DEPTHOGRAPH CHART BEFORE TUNING INSTRUMENT PIPING.

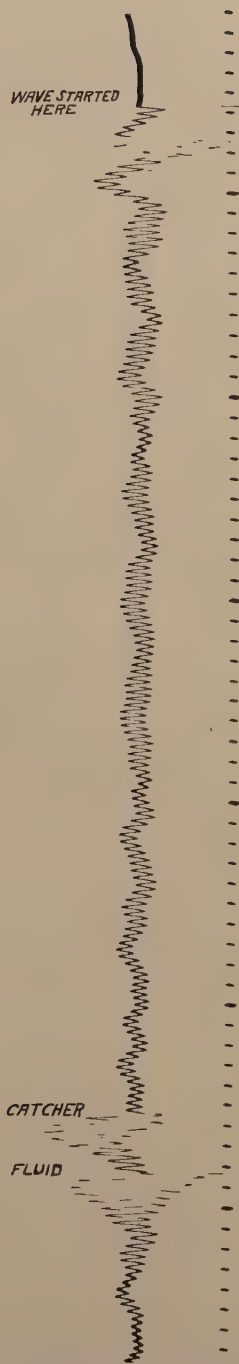


FIG. 6.—RESULT OF TUNING TO AMPLIFY COLLAR ECHOES.

cally all oil companies keep records from which the average length of the joints can be determined. Many of these records show the length of each stand and its position in the string of tubing. Having this information on the tubing and knowing the number of joints above the fluid level, it is obviously a simple matter to determine the fluid level in the well.

A condition of resonance is set up between the collar echoes coming out of the well and an oscillation that takes place in the piping between the recording instrument and the casinghead. When the length of this connecting pipe is so adjusted that perfect resonance is set up in it by the succession of collar echoes entering it from the well casing, the amplitude of the collar echoes is greatly increased, making it possible to readily count them on the photographic record.

When properly tuned the oscillation occurring in the pipe between the instrument and the well casing is three times the frequency of the collar echoes coming from the well, thus it becomes a third harmonic of the collar, or fundamental frequency, and the phase relation is such that the fundamental and third harmonic wave peaks coincide and result in a greatly increased fundamental or collar-echo amplitude.

Fig. 5 is a Depthograph chart taken before tuning the instrument piping and Fig. 6 shows the result of tuning it to amplify the tubing-collar echoes. The space between adjacent peaks on this chart represents one joint of tubing. There was a catcher in this well but its exact location was not known, making it necessary to determine the number of tubing joints above the fluid. The wave motion of the light-beam track on these charts is due to large quantities of gas bubbling out of the oil in the well.

This method permits measuring the distance to the fluid in a simple direct way where there is not a catcher or reflector in the well or where the catcher location is not known, or where the catcher or reflector is below the surface of the fluid.

SOLUTION OF PUMPING PROBLEMS

The Depthograph has been used principally for making fluid-level surveys of groups of wells in a field. It is, however, finding increased use as an aid in solving difficult pumping problems.

In producing wells the fluid is seldom as dense within the well as it is in a sample drawn from the well and from which the gas has been allowed to escape. Fluids made light in the well by gas are difficult to pump at satisfactory volumetric efficiencies even though a good conventional gas anchor may be used. Many wells have been pumped at low volumetric efficiency because it could not be determined whether there was lack of fluid in the well or whether the fluid was too light for the

pump to handle efficiently. The Depthograph has been used in many wells of this kind to determine the real reason for low volumetric efficiency.

In making a fluid-level test, if considerable fluid is found above the pump the operator usually wishes to know how much it is equivalent to in feet of dense fluid, or what the pressure is at the pump during normal operation. To determine this, the casing is closed in and the pressure

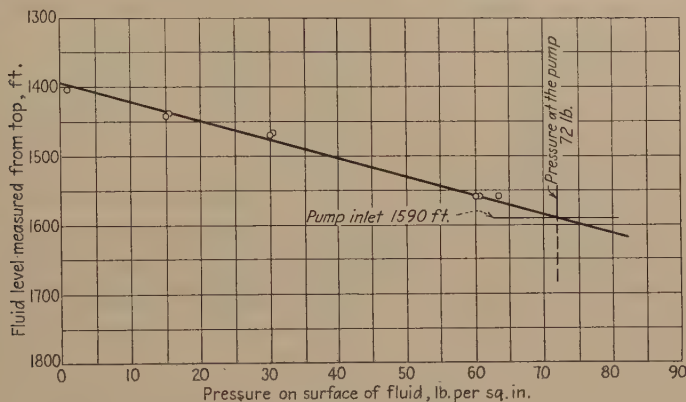


FIG. 7.—FLUID-LEVEL CURVE OF WELL IN WHICH FLUID WAS OF HIGH DENSITY.

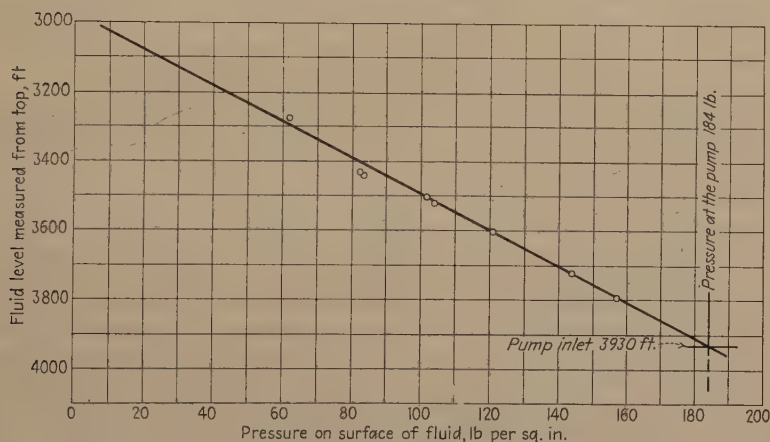


FIG. 8.—FLUID-LEVEL CURVE OF WELL IN WHICH FLUID WAS ABOUT 50 PER CENT NORMAL DENSITY.

allowed to build up to some predetermined value. When this pressure is reached the gas flow-line valve is cracked and the pressure held at the desired value for several hours, or until the fluid level has ceased to recede. The level is then photographed and its location determined. The total pressure holding the fluid down during this test is the sum of the static head due to the weight of the gas column above the fluid and the casing pressure at the top of the casing. Dividing this total pressure by the distance in feet through which the fluid had receded

gives the average density of the fluid in pounds per square inch per foot of static head.

To determine the density of the fluid at different distances above the pump, this back-pressure operation is sometimes repeated several times. As the well should be pumped until the level ceases to recede after each step of casing pressure it is seldom that more than one step can be completed in one day unless the casing is small and the quantity of gas large, which will permit making determinations more often. Figs. 7 and 8 show fluid-level curves plotted from such tests. The data for Fig. 7 were obtained from a wet well in which the fluid was of high density while the curve shown in Fig. 8 was plotted from data taken from a well where the fluid was about 50 per cent of normal density.

It has been found that if, when the level becomes stable, the distance the fluid in the well has been depressed is plotted against the corresponding pressure on the surface of the fluid, the result is practically a straight line. This permits the pressure at the pump to be determined although the fluid level at the time the last density-determination test is made may be a considerable distance above the pump. This is illustrated by Figs. 7 and 8.

DISCUSSION

(A. H. Bell *presiding*)

B. H. ROBINSON,* Los Angeles, Calif.—The Depthograph is a well designed instrument, and the theory of its operation is basically sound. This instrument records by an indirect method the same type of information that is recorded by the bottom-hole pressure gauge. The Depthograph has the advantage over the bottom-hole pressure gauge in that the equipment is located at the surface and rods or tubing or both do not have to be removed from the well to install it. A further advantage is that often the density of the fluid can be determined, and this is not practical with the pressure gauge in a pumping-well test because the gauge is at the bottom of the pump and to determine the gravity of the fluid a dynamometer is required in addition.

The value of any instrument depends upon the accuracy of the answer secured. In an attempt to evaluate the results of even small errors in measurement, the following example is presented. Assume fluid level and density of fluid are measured in a 2000-ft. well, and from this information the bottom-hole pressure is computed. In this particular well the fluid is found to be above the pump, indicating that the maximum production is not being secured. If indicated fluid level is accurate to within 2 per cent, there will be an error of 2000 times 0.02, which is 40 ft. With a fluid gradient of 0.4 lb. per sq. in. per foot of height, the error in bottom-hole pressure becomes 0.4 times 40, which is 16 lb. per sq. in. Productivity indices usually range from 0.1 to 10 bbl. per pound differential pressure California wells, so that the error in computing the additional available production rate will range between 1.6 and 160 bbl. per day. In a deep well the same percentage of accuracy will result in more serious errors. For instance, in a well similar to that just described but 8000 ft. deep, the error in fluid-level measurement is 160 ft. and the error in bottom-hole pressure

* General Petroleum Corporation of California.

is 64 lb. per sq. in., and the error in estimating potential production becomes a minimum of 6.4 bbl. per day and a maximum of 640 bbl. per day. As stated previously, the error used in the illustration is not a reflection on the accuracy or actual error of the Depthograph. It simply points out some of the difficulties of our problem. I understand that with the use of reflectors or with the use of tubing catchers to accompany the pump very accurate results have been secured.

C. P. WALKER.—That all depends upon the accuracy with which the reflectors have been measured in. Most of them have been located very close to the fluid. Frequently we build up casing pressure until the stabilized fluid level is at or very close to the pump. We can tell when the fluid is at the pump intake, in which case there is no error in the fluid-level determination.

MEMBER.—Tubing catchers are rather expensive. Cannot something else be used to reflect the wave?

C. P. WALKER.—Reflectors may be installed in lieu of tubing catchers. They usually consist of pieces of light-weight casing swedged down at both ends and then bored to fit over the tubing, where they are secured by means of set screws. Some operators object to the addition of rigid reflectors so our design of reflector consists of a sheet-iron cylinder with conical ends welded to collars for slipping on over the string of tubing at any desired location. The making costs only a few dollars each.

M. W. MORRIS,* Taft, Calif.—There is an interesting application of the Depthograph which has not been mentioned here; that is, to locate holes in well casing. The position of the break in the pipe is indicated by a negative reflection of the pressure wave.

* Petroleum Engineer, Standard Oil Company of California.

Use of Data on the Build-up of Bottom-hole Pressures

BY MORRIS MUSKAT*

(Fort Worth Meeting, October, 1936)

IN preparing a well for pumping, observations are often made of the fluid level in the well bore or bottom-hole pressures at various times before equilibrium has set in. From a qualitative point of view one may immediately infer that if the rise in the bottom-hole pressure or fluid level is rapid the permeability of the sand about the well bore is large, and converse conclusions may be drawn if the rise is slow. However, a more quantitative estimate will give additional information of value, as will be shown in this paper.

To derive such an estimate we may proceed as follows. Let h be the fluid height, above the sand face, at time t , and let γ_0 be the average density of the fluid that enters the bore. The bottom-hole pressure, for a fluid height h will therefore be $p = \gamma_0 g h$, neglecting, of course, the friction drop in the well bore, while the fluid is rising, as may be justifiably done for most pumping wells.

If a is the free area of the open-flow string—assumed to be uniform—the rate of production from the sand during the rise of fluid will be:

$$Q = a \frac{\partial h}{\partial t} = \frac{a}{\gamma_0 g} \frac{\partial p}{\partial t} = f(p) \quad [1]^1$$

where the last part of the equation merely indicates that, in general, the production rate Q must be considered as a function of the back pressure, and is determined by it alone. In fact, equation 1 shows that if the rate of rise of the pressure or fluid level is determined as a function of the height of rise, or p , for a number of values of the latter, this functional relation between Q and p will be immediately given.

Conversely, if we know this functional relation, the rate of increase of p or h may be predicted, or, by observing the rate of rise of p or h some of the constants of the sand may be determined. Thus we may approximate the production from a well in a pumping state by that of a dead

Manuscript received at the office of the Institute Sept. 8, 1936.

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¹ Equation 1 implies that the increasing bottom-hole pressure is due only to the rising fluid head. It will, therefore, break down in the case of flowing wells after shutting in, where the compression of the gas in the well bore will give an additional time-varying contribution to the bottom-hole pressures.

fluid, and neglect the effect of the gas on the law of flow². We shall have then:

$$Q = c(p_e - p) \quad [2]$$

where c is a constant depending on the dimensions of the system (sand thickness, well radius, "external" radius) and is proportional to the sand permeability, and p_e is the reservoir pressure. With this form for Q , the integral of eq. 1 takes the form:

$$p = p_i + (p_e - p_i)(1 - e^{-\gamma_0 g c t / a}) \quad [3]$$

or

$$h = h_i + (h_e - h_i)(1 - e^{-\gamma_0 g c t / a}) \quad [4]$$

where, since $p = p_e$ and $h = h_e$ at $t = \infty$, p_e and h_e correspond to the actual closed-in bottom-hole pressure and the final equilibrium fluid level, respectively, and p_i and h_i are the initial values of the bottom-hole pressure or fluid height; i.e., those at the instant chosen to represent $t = 0$.

Rewriting equations 3 and 4 in the forms:

$$-\frac{\gamma_0 g c t}{a} = \log \frac{p_e - p}{p_e - p_i} = \log \frac{h_e - h}{h_e - h_i} \quad [5]^3$$

we see that if the time is observed for the rise in the pressure or fluid height to the values p or h , and if the final equilibrium pressure or fluid height p_e , h_e is known, as well as the area of the hole a and the fluid density, equation 5 will give the value of c as:

$$c = \frac{a}{\gamma_0 g t} \log \frac{p_e - p_i}{p_e - p} = \frac{a}{\gamma_0 g t} \log \frac{h_e - h_i}{h_e - h} \quad [6]$$

And if c is known, the production capacity of the well for any back pressure follows from equation 2. Thus the maximum pumping capacity would be ($p = 0$):

$$Q = c p_e = \frac{a p_e}{\gamma_0 g t} \log \frac{p_e - p_i}{p_e - p} = \frac{a h_e}{t} \log \frac{h_e - h_i}{h_e - h} \quad [7]$$

In the latter form one does not need to know the fluid density. However, it should be mentioned that the observations of the pressure p or height h should be made for values that are not very close to the equilibrium

² In fact, if one should extrapolate to consolidated sands the results recently established for the flow of gas-liquid mixtures through unconsolidated sands [R. D. Wyckoff and H. G. Botset, and M. Muskat and M. W. Meres: *Physics* (1936) 7, 325, 346] it would appear that equation 2 may be a good approximation even if the oil and gas should flow as a "live" fluid, except during the first stages of the pressure build-up when the liquid saturation about the well bore may show an appreciable increase. The constant c will then, of course, no longer be given rigorously by equation 8.

³ All logs are to the base e , or natural logs.

values p_e , h_e , or else small errors in the measurement of p or h will give a relatively large error in the value of c and in Q .

If the times are observed for more than one pressure or fluid height, they should give the same value of c as computed by equation 6 provided equation 2 is correct. Or, the data may be plotted on semilogarithmic paper with t on the cartesian scale and $p_e - p$ or $h_e - h$ on the logarithmic scale; the points should then lie on a straight line, the slope of which will give the value $\gamma_0 gc/a$.

If equation 2 is found to hold—i.e., if the above plot does give a straight line—the constant c may be resolved theoretically into the form:

$$c = (2\pi kb/\mu)/\log r_e/r_w \quad [8]^4$$

where k is the sand permeability, b its thickness, μ the viscosity of the oil, r_w the well radius and r_e the external radius at which the pressure is p_e , under flowing conditions. If, then, c is determined by the above method and the sand thickness and radii r_w , r_e are known, the sand permeability may also be computed.

A deviation of the plot of $p_e - p$ or $h_e - h$ against t on semilogarithmic paper from a straight line may be due to one of two reasons. Either the flow is not like that of a dead liquid, so that equation 2 is not valid, or the value of p_e or h_e , from which is subtracted the observed p or h , is incorrect. A choice between these alternatives may be made by attempting to straighten out the curve by changing the value of p_e or h_e . If this is unsuccessful, the incorrectness of equation 2 is established. If, however, a straight line is obtained, equation 2 will not only be verified but the correct value of p_e or h_e will at the same time be obtained.

In fact, this adjustment of p_e or h_e so as to make the plot of $p_e - p$ or $h_e - h$ versus t a straight line, on semilogarithmic paper, affords both a rapid and very sensitive method for determining the true reservoir pressure. For if the sand be "tight" it may take several days or more for the reservoir pressure to be built up at the bottom of the well bore, so that the cost of determining the reservoir pressure will be prohibitive. If, however, bottom-hole pressures or fluid heights be recorded simply for a pressure-differential variation of some twentyfold over a 10 to 20-hr. interval, during the period of appreciable rate of increase, the above method will permit the determination of p_e or h_e without the necessity of waiting for equilibrium to be established. At the same time the value so obtained will be very accurate, as errors in the assumed value of p_e as low as 5 lb. will cause an easily detected deviation of the plot from strict linearity over a pressure range such as 40 to 800 pounds.

⁴ It is assumed here that the well completely penetrates the producing sand. If this is not true, and the actual well penetration is known, a correction factor must be applied. This will be found in the paper by R. D. Wyckoff, H. G. Botset, M. Muskat, and D. W. Reed: Amer. Assn. Petr. Geol. (1934) 18, 161, Fig. 7.

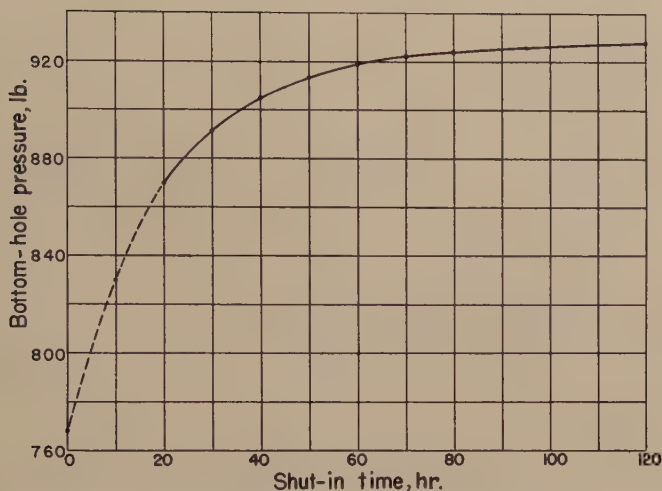


FIG. 1.—AVERAGE BOTTOM-HOLE PRESSURE RISE FOR 20 WELLS IN THE JUDKINS FIELD, ECTOR COUNTY, TEXAS, MARCH 1935.

The author is grateful to Mr. G. A. Pool, Chairman of the Judkins Pool Engineering Committee, for permission to publish this curve.

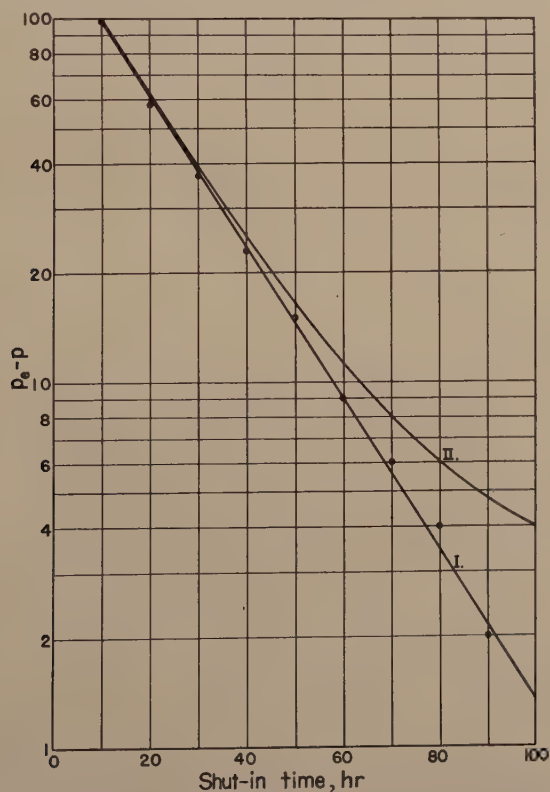


FIG. 2.—DATA OF FIG. 1 REPLOTED ON A SEMILOGARITHMIC SCALE.

$p_e - p$ = reservoir pressure - bottom-hole pressure. Curve I: $p_e = 928$ lb. curve II: $p_e = 930$ lb.

Although the author has not had available suitable field data with which to test satisfactorily the above theoretical results, the manner of the determination of the reservoir pressure may be illustrated by an application of the above outlined procedure to the data shown in Fig. 1, giving the average rate of increase in the bottom-hole pressures of 20 wells in the Judkins field, Texas. When plotted on semilogarithmic paper, with the reservoir pressure p_e taken as 928 lb., these data give the straight line, curve I, of Fig. 2. If the data had referred to a single well, this linearity would have been evidence of the general validity of the above theory for that case, and not essentially fortuitous, as actually it is. Furthermore, the sensitivity of this test to the value 928 lb. for p_e is strikingly shown by comparison of curve I with curve II, in which the same data are plotted, but with $p_e = 930$ pounds.

It is hoped that with a knowledge of the possible applications of such field data as used above, it will be found feasible to collect at least enough to determine their value from a practical point of view⁵.

ACKNOWLEDGMENTS

The author is indebted to Mr. R. D. Wyckoff for helpful discussions of this problem, and to Dr. P. D. Foote, the Executive Vice-President of the Gulf Research & Development Co. for permission to publish this paper.

⁵ A study of this kind is now being conducted by E. W. Kemler and G. A. Pool, of the Gulf Oil Corporation.

Influence of Production Practices on Gravity of Produced Oil

BY ROBERT R. BOYD,* MEMBER A.I.M.E.

(Los Angeles Meeting, October, 1937)

THE gravity discussed here is that of the clean oil produced. Gravities of fluids containing water, free or in the form of emulsion, sand, drilling mud or mineral salts of a nonbituminous nature do not represent the gravity of crude oil as considered in this paper.

During recent years it has become a frequent occurrence for operators to be called upon to explain to landowners the reasons for variations in gravity on shipments of oil from wells in which they are interested as royalty owners. In regard to single well leases it has been noted that marked changes in gravity frequently have occurred for no apparent reason. Data collected on the subject and correlated with production methods reveal interesting facts. It is the purpose of this paper to present some of the highlights on the subject.

These gravity changes in the natural crude oil are with a few exceptions the result of the liberation under varying conditions of the volatile hydrocarbons from the natural oil-gas solution contained within the pool. The subject of the liberation of gases from natural oil-gas solution has been investigated by Ben E. Lindsly, of the U. S. Bureau of Mines, and the observations recorded here are in the main consistent with his conclusions.

Investigators have recognized two methods of liberation of gas from solution—flash and differential. In the latter method the vapors are removed from the liquid as rapidly as formed and have no opportunity to come to a condition of equilibrium with the oil. In flash liberation an equilibrium condition between the oil and the gas exists at the pressure of separation. Mr. Lindsly has found that the method of liberating the gas from the oil has a pronounced effect on the final gravity and that differential liberation results in a higher A.P.I. gravity due to the higher ratio of gasoline producing hydrocarbons left in the oil.

Under actual production practices with high velocities in flow strings, it is our contention that conditions of perfect equilibrium between gas and the oil rarely exist, and that gas separation is made under varying conditions, sometimes approaching that of equilibrium and at other times departing from it.

Manuscript received at the office of the Institute Oct. 13, 1936.

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It has been pointed out that the gravity of the oil-gas solution in a natural reservoir under pressure is much lighter, because of the dissolved gas, than is the gravity of the oil as delivered to the production tanks. From a production standpoint it is desirable to distinguish between the gravity of the oil-gas solution in the reservoir and that of the oil component. As the gravity of the residual oil will vary with the changing conditions under which the gas component is liberated, we may define the gravity of the oil within the reservoir as the gravity of the liquid hydrocarbon content of the reservoir when reduced to atmospheric pressure under conditions of differential liberation. We may not be able to measure this gravity accurately unless we get a bottom-hole sample under static conditions, nevertheless we shall adopt the definition.

A discussion covering the changes in gravity of crude oil brought about through methods of production involves two separate phases:

1. The gravity changes of the fluid within the reservoir.
2. Gravity changes brought about in the wells, lines and traps, by the methods of operation.

GRAVITY CHANGES WITHIN THE RESERVOIR

Gravity changes within the reservoir may be brought about by migration. A decrease in the gravity of the oil in an old field under water drive is a common phenomenon. Occasionally an increase in gravity has been noted after prolonged periods of pumping, which may be ascribed to a downward migration of lighter oil originally accumulated on the top of the structure, the downward migration having been caused by edge withdrawals.

The method of gas liberation in the reservoir naturally has a bearing on the gravity of the oil entering the well. Without arguing whether or not this method more nearly approaches flash liberation or is approximately differential liberation, we can admit that it varies between the two methods, and also that it is influenced by the position of the well on the structure, the presence or absence of a free gas cap, and the method of pressure control on the well.

GRAVITY CHANGES CAUSED BY PRODUCING OPERATIONS

It is obvious that an increase in casinghead gasoline from the well must result in the lowering of the gravity of the oil produced, except when such gasoline is recovered from a product that previously was lost, or when it is drawn from oil still left in the ground. In the first instance the economic gain is clear. In the second, an ultimate loss is indicated as casinghead gasoline produced from the oil left in the ground necessarily lowers the gravity of the oil remaining, thus lowering its value and making its recovery more difficult.

It often happens that a justification of a change in production is based on an increased gasoline recovery from the gas produced with the oil. Except as noted above, increased production of casinghead gasoline can occur only when such gasoline is taken directly from the oil produced, thus lowering the gravity and its value, the net results to the operator remaining substantially the same. Changes in gravity of as much as 4° A.P.I. on 30° oil have been brought about by operating practices within the control of the operator. The changes in gravity were accompanied by an equalizing change in natural gasoline production. The producer is primarily interested in producing the maximum amount of oil at a minimum cost, and is not greatly concerned with the effect of his production method on the gravity of the oil as long as the gasoline-producing fractions are all recovered in the gasoline plant.

There are some reasons, however, why we should have a better understanding of the causes of these gravity fluctuations, among them the following:

1. Gasoline production may be erroneously credited to an operation that has merely resulted in extracting the gasoline from the oil produced.
2. Geologists may err when using gravity data as an aid in determining the horizon from which the production originates.
3. Claims have arisen for the improper accounting of royalties, based on the theory that the gravity of the produced oil varies uniformly with the time the well has been on production.
4. A knowledge of the subject may enable the producer to use the gravity data as an aid in solving production problems, including those which have to do with reservoir withdrawals.

The following data are presented covering changes in gravity that have resulted from changes in well operations. The gravity figure used is that of the average of all tank gravities for each month and, unless otherwise noted, represents the gravity of oil cutting 1 per cent or less in water and sediment.

Effect of Release of Pressure on Well Head.—Fig. 1 shows the result of a sudden drop in well-head pressure. On this chart, in addition to the gravity range, has been plotted oil production in barrels per day and the back pressure on the flow string. Through the first 21 months of the life of the well, the tubing pressure dropped from 290 lb. per sq. in. to 70 lb. with little change in the gravity of the oil. The gas was separated in a trap carrying 5 to 10 lb. The gas-oil ratio varied considerably, gradually making two complete cycles between 1500 and 2300 cu. ft. per barrel. With 60 lb. carried in the tubing, the well ceased to flow. The choke was removed and the well was placed on production by means of the gas-lift, which was immediately discontinued. The well continued to flow against 5 to 10 lb. pressure carried on the trap. The results were as given in Table 1.

Effect of Changing from Flowing to Gas-lift Operations.—Fig. 2 shows a clear record of the effect on the gravity of placing a flowing well on gas-lift. During the four-year flowing life, the gravity ranged between 29.4° and 30.7° A.P.I. As a probable cause of varying gravities, one

TABLE 1.—*Effect of Release of Pressure on Well Head*

	Before Change	After Change
Well-head pressure, lb. per sq. in.....	70	10
Trap pressure, lb. per sq. in.....	10	10
Gas-oil ratio, cu. ft. per bbl.....	1240	1726
Saturation of gas, gal. gasoline per M. cu. ft.....	2.81	4.01
Natural gasoline, gal. per bbl. oil.....	3.48	6.92
Gravity of oil in flow tank.....	30.3°	28.4°
Oil per day, bbl.....	412	650

might suggest the varying conditions of equilibrium within the flow string and in the drainage area immediately surrounding the well. The highest gravity was observed on the first month of production and the lowest on the fifth month. This low point was followed by a steady increase for

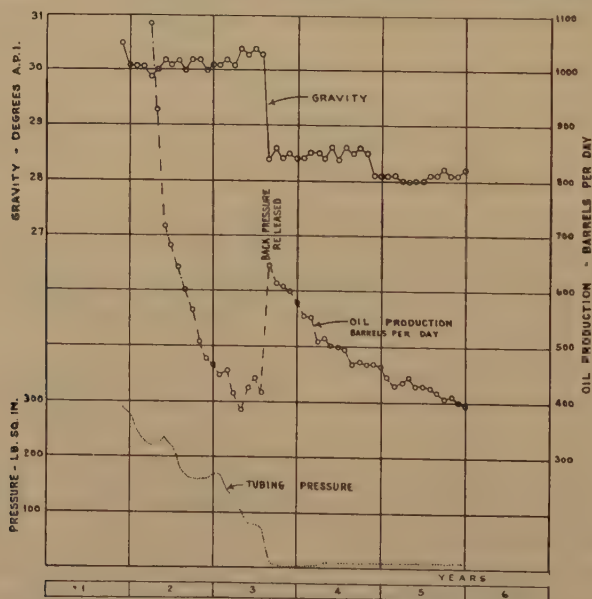


FIG. 1.—EFFECT OF RELEASE OF PRESSURE ON THE WELL HEAD.

two years. When the well was finally placed on gas-lift, there was an immediate drop of 1.5° in gravity. The low point observed under gas-lift operations was 27.2°. Under pumping operations the gravity again reached 30.0°, with an average over a considerable period of time of 29.8°.

The effect of the gas-lift is not always immediately noticeable. Usually its application increases the pressure against the formation so that more gas is retained in solution as the oil enters the well. At first this may partly neutralize the effect of the introduction of the dry gas.

The example shown is typical, although there have been instances when the introduction of a small amount of dry gas into a naturally flowing well was not immediately followed by a noticeable change in gravity. The usual drop did take place later however, when the quantity recycled was increased.

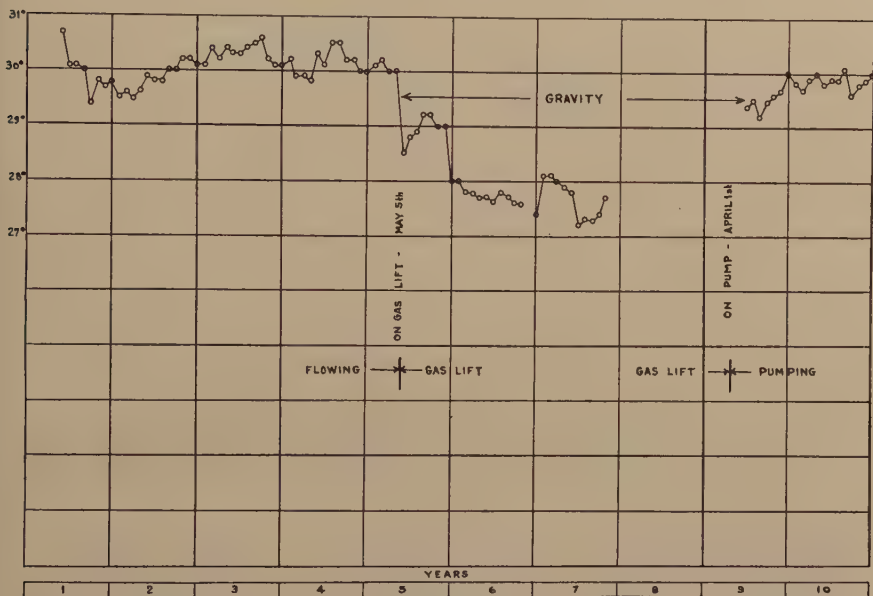


FIG. 2.—EFFECT ON GRAVITY OF CHANGING FROM FLOWING TO GAS-LIFT OPERATIONS.

Wet versus Dry Gas Circulation.—Fig. 3 shows the difference between wet gas and dry gas in gas-lift operations. The well recorded was brought in with a highest observed gravity of 29.5° A.P.I. and a gas-oil ratio of 1880 cu. ft. per barrel. The gasoline recovery was 1.58 gal. per 1000 cu. ft., making about 2.84 gal. of natural gasoline recovered per barrel of oil. Production was started with the compressor, but the well flowed without aid after once started. The tubing pressure dropped from 475 to 125 lb. in 25 days, and to 35 lb. before the well went on gas-lift. The gas-oil ratio had a uniform increase to 2300. A pressure of 3 to 5 lb. was carried on the trap. The gasoline recovery increased to 1.93 gal. per thousand or 4.43 gal. per barrel of oil. Wax trouble in the upper part of the tubing became serious during the second year.

Under dry gas circulation, the gravity varied considerably, as recorded on several other charts, reaching a minimum of 26.9° A.P.I.

In the fourth year, the absorption plant was shut down and wet gas instead of dry gas was recycled. This was followed by an immediate increase in the gravity of the oil to a point equal to or in excess of the initial observed gravity. The effects of the change are shown in Table 2.

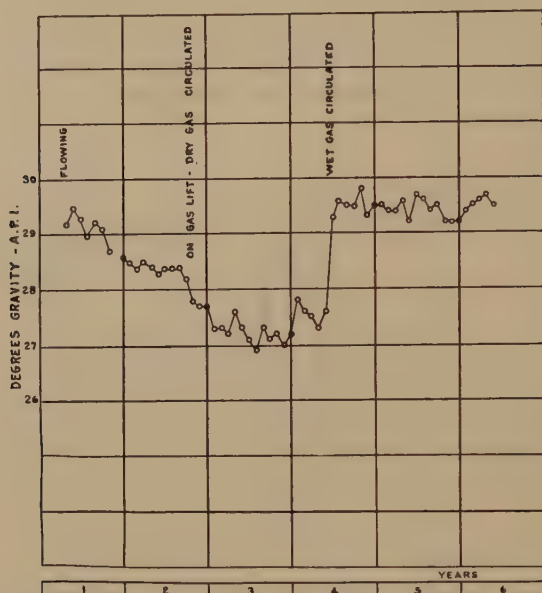


FIG. 3.—EFFECT OF SUBSTITUTING WET GAS CIRCULATION FOR DRY GAS IN GAS-LIFT OPERATIONS.

Wax trouble in the upper 1000 ft. of the flow string ceased entirely under wet gas circulation.

TABLE 2.—*Wet Gas versus Dry Gas*

Production under dry gas circulation:

Barrels oil per day.....	129.4
Barrels natural gasoline.....	13.4

Total..... 142.8

Average gravity of crude oil..... 27.4° A.P.I.

Production under wet gas circulation:

Barrels oil per day.....	146.5
Barrels natural gasoline.....	6.9

Total..... 153.4

Average gravity of crude oil..... 29.6° A.P.I.

Effect of Periodic Intervals of Idleness.—Fig. 4 shows the effect on gravity of shutting in a well and allowing the fluid level to build up on the pump. The oil from this well had a slight cut, which has been indicated at the bottom of the chart. The days on production each month

are also indicated. The practice on this well was to allow it to produce its allotment each month. This was done by producing for a sufficient number of days at the end of one month and continuing on into the next month. The well was then closed in for a period of perhaps 20 or 30 days. There are periods, however, of several consecutive months when no curtailment was taken. After each shut-in period, there were high points on gravity followed by low points after the well had been on production a few weeks. Where there was continuous production there was continuous low. This well was shut in at one time while producing 23.8° oil.

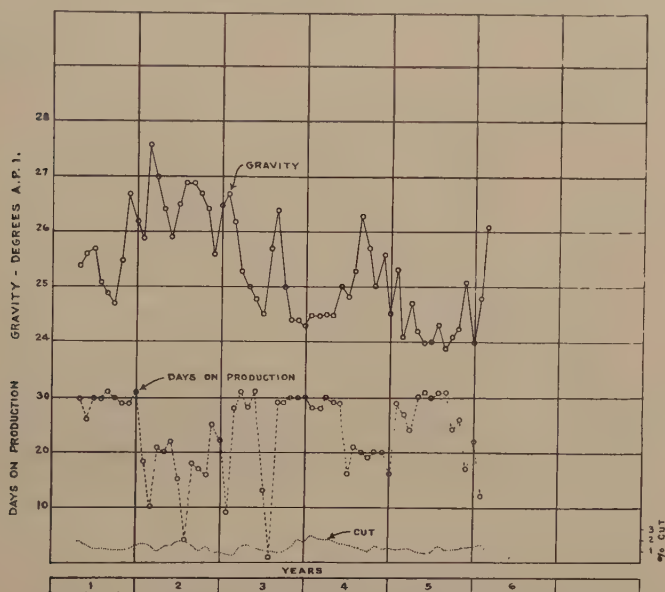


FIG. 4.—EFFECT OF PRODUCING WELLS WITH PERIODIC INTERVALS OF IDLENESS.

After being closed in for one month, on being placed on production, successive tanks during the next month had the following gravities: 26.7°, 26.3°, 25.6°, 24.7°, 24.7°, 24.0°.

In contrast to this graph, some pumping wells that are producing continuously show a close approximation to a straight-line decline in gravity. One record covering several years of a Brown zone well, at Long Beach, shows a drop of 1.3° A.P.I. in that time, with only 10 months where the gravity falls more than 0.2° above or below a straight line drawn between the beginning and end of the record. The extremes in variation are 0.5° above the line and 0.3° below the line.

Effect of Vacuum on the Casinghead.—On Fig. 5 are plotted the gravity by months, the oil production by months in barrels, and the natural gasoline production by months in gallons. Roughly, the relation throughout is one gallon of natural gasoline per barrel of oil.

The irregularities of the production curve are caused by curtailment. During the period of high fluid levels, the ratio of gasoline to oil drops and the gravity increases.

Production methods of the offsets involved the use of a vacuum, which caused the same method to be used here. As no appreciable improvement was noted in the oil production, the practice was stopped, with the result that gas production dropped to zero with no improvement in the oil gravity. The practice was then resumed increasing the amount of vacuum, resulting in the production from the gas of 11 gal. of gasoline per barrel of oil, a quantity far in excess of the amount drawn from the oil produced indicating the extraction of gasoline from oil still left in

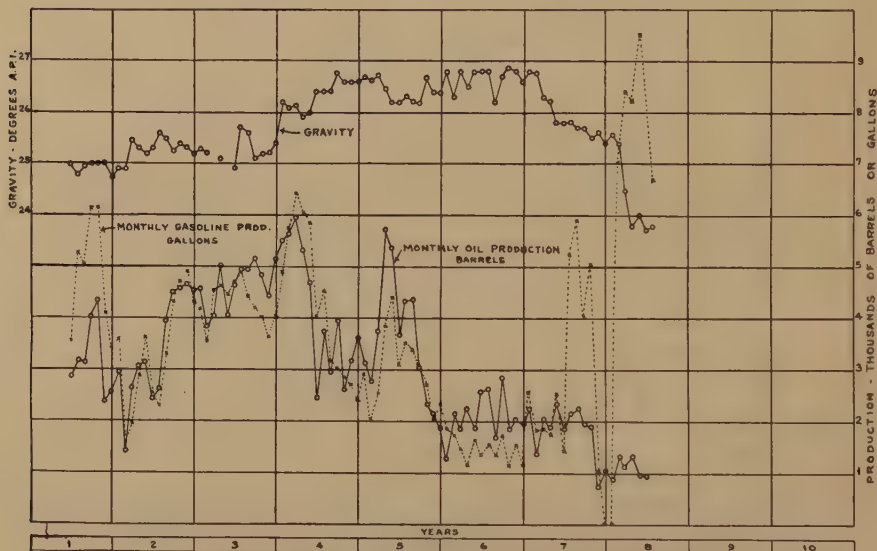


FIG. 5.—EFFECT OF A VACUUM ON THE CASINGHEAD.

the ground. The evil effects are appearing at the end of the graph, with a decreasing gasoline production and no improvement in the quantity or quality of the oil produced, which has already been bled of a considerable part of its gasoline content before it enters the well.

EFFECT OF HIGH-PRESSURE TRAPS

If the primary separation of gas is made at high pressure, we may expect to conserve the gravity of the oil. Mr. Lindsly has discussed this matter at length, so we will merely submit some data on a well that had been producing for some months previous to the installation of the high-pressure trap (Table 3).

CONCLUSIONS

As a result of the data we have accumulated, we can conclude that the following operating conditions help to retain the heavier vapor in

the oil and therefore conserve its gravity: (1) carefully regulated pressure control at the well head; (2) primary separation of gas at high pressure; (3) use of wet gas in gas-lift work; (4) high fluid levels; (5) smooth pumping motion.

TABLE 3.—*Effect of High-pressure Trap*

	A.P.I. Gravity of Oil	Gasoline Produced, Gal. per Bbl. Oil
Before high-pressure trap was used.....	29.2°	7.38
During use of 360-lb. trap.....	30.6°	4.56
On gas-lift ^a	26.6°	11.8

^a There are no gravity data for the later stages of the flowing period, therefore the gas-lift figures cover a period some two years longer than the others. When the well was pumped later the gravity of the oil was around 30.0° A.P.I.

Some of the causes of abrupt drop in gravity are as follows: (1) marked drops in well-head or trap pressures; (2) circulation of dry gas for gas-lift work; (3) low fluid levels; (4) poor pump operations.

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DISCUSSION

(A. H. Bell presiding)

S. C. HEROLD,* Glendale, Calif.—This paper seems to me to illustrate the principle that when we are producing oil and gas we are dealing with something very closely related to events taking place in an absorption plant. If we change the conditions of production in any way whatever we alter the amount of gas that comes with the oil from the well. We have, in fact, a choice in producing gasoline from the well—we can take it either with the oil or with the gas. This paper illustrates the fact that each change in production causes a change in the gasoline content of the gas and that of the oil. Naturally, if a greater amount of gasoline is allowed to come with the gas, a smaller amount is allowed to come with the oil, and because of this smaller amount the gravity of the oil itself is decreased.

The author says that geologists may err when using gravity data. I suppose it would be true that if we could produce our wells without manipulating them in any way whatever the gravity of the oil would decrease throughout production. If we are trying to picture the situation existing within a reservoir or a structure, we know that the gas tends to accumulate on the crest and that water surrounds the pool. We may expect, before the first well is drilled, that there is a gas cap or something of

* Consulting Engineer.

the nature of the gas cap on the top, that there is more free gas there than elsewhere in the reservoir, and that there is more gasoline on the crest per acre-foot of formation than there is on the edge of the pool near the water. But this does not mean that since the gas in the gas cap has a greater amount of gasoline the oil to the extent that it exists on the crest has less gasoline. We may, in fact, expect on the crest a high gasoline content of gas and a light gravity of oil, because of dissolved lighter fractions in such oil.

It is not as simple to regulate production of gas in California as it is in some other fields. In fact, it is not easy to conserve gas in this state. We often regulate well performances for the purpose of controlling encroachment of water in the vicinity of the well. Gas production, water production, water encroachment, rather than oil production itself, are all very sensitive to manipulation of wells in California. Necessarily, then, there will be erratic changes in gravity at times in our fields; we cannot hope to produce oil in the ideal way, in a way in which we are led to believe it is being produced in the Mid-Continent field.

It is impossible for the Mid-Continent field to have the variations in gravity that exist in California. Every well there has its own drainage area while every well in California is producing from one large reservoir. Gas cannot shoot from one well location to another in that area, whereas here it does so, carrying gasoline with it. As a consequence it is obvious that the gravity of oil can change almost daily in California, whereas it cannot do so to the same degree in the Mid-Continent. The approach of water to a well seems to mean a change in the gravity of oil. In the Mid-Continent field there is no such approach of water. In the Cushing field of Oklahoma, the water line surrounding the pool was located soon after discovery of the field in 1915. Now over five hundred million barrels of oil has been taken out of that field, and yet the water line is today where it was in 1915.

There is no field in California like the Cushing field. Encroachment here is sometimes very difficult to measure but we can at least measure some movement towards definitely located edge wells. These wells respond by increasing the proportional production of water. In view of the fact that there is more trouble with water here than in the Mid-Continent, I do not believe we deserve some of the criticism we have had in the past regarding the manner in which we handle our wells, especially with respect to the amount of water itself, changes in the gravity of the oil and the changes in the gasoline content of the gas.

Concerning the maintenance of pressure in the reservoir, when we in California get a sufficient number of wells to satisfy demand with a prorated production of 25 or 50 bbl. per well, then we too can maintain the pressure in our reservoirs; and when we finish our Pliocene and Miocene production and drill down to the Permian, Pennsylvanian, Mississippian, Devonian, and Silurian formations, provided they exist, then we too can do as well as they do in the Mid-Continent field.

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BY P. E. FITZGERALD† AND J. C. GINDLESPIRGER‡

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Recent Developments Related to Petroleum Engineering

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(Los Angeles Meeting, October, 1936)

RECENT developments related to petroleum engineering discussed in this paper are:

1. Drilling wells in with oil or the use of chemical compounds or "mud solvents" for removing rotary mud from wells in order to increase or make possible oil production.
2. Comparison of results of electrical logging methods in locating water, as shown in a recent test on a well in the Los Angeles Basin.
3. A new method for logging formations through casing, known as the Stratagraph.

DRILLING WELLS IN WITH OIL OR THE USE OF CHEMICAL COMPOUNDS OR MUD SOLVENTS

During the time that the California fields showed high gas pressures, the pressure of the gas within the formation was sufficiently great to break down the mud wall or cake formed while the well was drilling. That this did not always occur was demonstrated by the fact that in some of the older fields new wells sometimes had substantially higher initial productions than other wells near by. The explanation seemed to be that some sands were mudded off in the original drilling. Their pressure was then not great enough to break down the mud wall in competition with the higher pressure of the sands, but the situation reversed itself so that a later well benefited by the pressure in these originally weaker sands. As time passed, in wells deeper than 5000 ft. the difficulty of bringing wells on production became more pronounced. This led to a hunt for substitutes, of which a number have been tried. The one that has proved most successful in our experience at Ventura is known as the Nobs solvent.

At well No. 1 of the Associated-Ventura Land & Water Co. when it was recompleted in February 1936, about 10 days were spent in trying to bring the well in in the regular manner, but only about 113 bbl. of water could be swabbed from the well, and even this quantity decreased as time passed. The Nobs solvent was spotted in the bottom of the hole opposite the perforations, inverted Guiberson swab rubbers were used on the drill pipe and the hole was down-swabbed in stages, beginning

Manuscript received at the office of the Institute Oct. 13, 1936.

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at the bottom of the hole. The well was allowed to stand and the mud was bailed from the hole. The down-swabbing was repeated and, after standing, mud was again bailed from the hole. This operation was continued as long as substantial quantities of mud were secured. It is estimated that more than two tons of solid material was taken from this particular well. When the well was placed on the pump, it built up a production of more than 200 bbl. of oil per day in less than 10 days, and at present is making 300 bbl. gross and 279 bbl. net. Its production is as great as that of old wells drilled during the time that gas pressures were high. This experience has been checked in several other wells.

In spite of this, however, it must not be assumed that the solvent is a cure for all drilling troubles. Neither can it be said that it represents a final method of completing wells.

Another method being used is to use oil as a circulating fluid in drilling wells in, rather than mud. In one well recently drilled, circulation was not re-established to the surface in drilling the last 800 ft. of hole. About 18,000 bbl. of oil were used as drilling fluid. Despite this fact, the cuttings made in drilling seemed to have gone into cavities or into formations in such a way as not to interfere with the production of the well upon completion.

Experiments are still being conducted with oil as a drilling fluid and with the Nobs solvent for removing the rotary mud. The great fear that formerly existed when well pressures were high—that wells could not be drilled in at great depths after the gas pressure was gone—has, therefore, been eliminated by both of these methods. It is reasonable to hope that further improvements in the art of drilling will make it possible to secure all the production possible at a location without danger of mudding the sands so as to interfere with production.

RESULTS OF ELECTRICAL LOGGING METHODS IN LOCATING WATER

As is well known in California, there are at least two service companies that make electrical logs of drilling wells. In recent months one of these companies has stressed particularly its ability to detect the presence of water in oil horizons. The other service company has always made a similar claim, but has not particularly stressed this part of its service. There are times when the value of this information is very great.

In the drilling of an edge well in one of the fields in the Los Angeles Basin, in order to make the best record possible, engineers of the Associated Oil Co. decided to core carefully the bottom 700 ft. of the hole. The first expected cementing point was around 6000 ft., but streaks of gray sand were found with the oil sand, so that the coring was carried on to 6212 ft., where after more than 50 ft. of oil sand had been found below a shale body, it was decided to cement the water string in the shale.

A successful shutoff was secured. As a precaution, it was decided to core the entire oil zone. Continuous coring, beginning at 6212 ft., was carried on to 6605 ft. One may well imagine the disappointment that resulted from finding gray sand about 4 ft. below 6212 ft. While the core recovery was remarkable during this entire interval, only 3 ft. of the last 15 ft. were recovered, consisting of 1 ft. of loose, coarse-grained oil sand and 2 ft. of firm oil sand.

The two competing electrical coring instruments were run. One was able to run to a depth of 6598 ft.; the other ran to a depth of 6605 ft., but the right-hand side of its record was missing below 6560 ft. The operator reported best saturation from 6530 to 6595 ft. Based on coring, a cementing point of 6410 ft. was chosen, and this point was selected as the proper cementing point by one of the service companies.

With the assurance of the core record, therefore, that nothing but oil sand was cored in the bottom of the hole, with the encouragement of one of the service companies that the best saturation was from 6530 to 6595 ft., and with no warning from the service company that stressed its claim to identify salt water in oil zones, everything seemed to indicate that there was no trouble ahead. But when the well came in it produced 300 bbl. of oil and 100 bbl. of salt water. In fairness to the service company that stressed its ability to locate salt water, it should again be stated that the right-hand curve of the record submitted, from which the water determination was to be based, ended at 6560 ft. In so far, however, as the oil company is concerned, the hole was open to 6505 ft. and the right-hand part of the record was made to that depth.

When the well proved to be wet it was necessary to kill it and have a third service company make a run to locate the water. A very fine record, showing the location of the water from 6580 to 6595 ft., was secured just about in the interval where the last core failed to get a satisfactory recovery and also within the depths to which both service companies were able to run their instruments. The well was then plugged with cement to 6546 ft. When placed on production, and even after washing with the Nobs solvent, it was impossible to get more than about 100 bbl. of fluid out of the hole, of which about half was water and the rest oil. This last evidence confirmed the last test made by the water-locating company that the water was in the bottom of the well. It did not conflict with the coring evidence because most of the last core was not recovered. One of the service companies again reviewed its record and claimed that, in addition to indicating as reported, the best saturation was from 6530 to 6598 ft., the record had been interpreted incompletely and that evidence of water at 6585 to 6590 ft. was indicated by a breaking back of its right-hand curve.

The story of this well is told principally to bring out the fact that there is still room for progress in those methods of electrical coring that

from the same run attempt to identify the location of sands, shales and waters. It is sincerely to be hoped that progress in this direction will yet be made. Otherwise, it will still be necessary to rely on the water-locating devices that make their runs especially for the purpose of locating water.

LOGGING FORMATIONS THROUGH CASING

During the past year and a half the Oil Well Water Locating Co. has been experimenting in the hope of logging formations behind casings. It

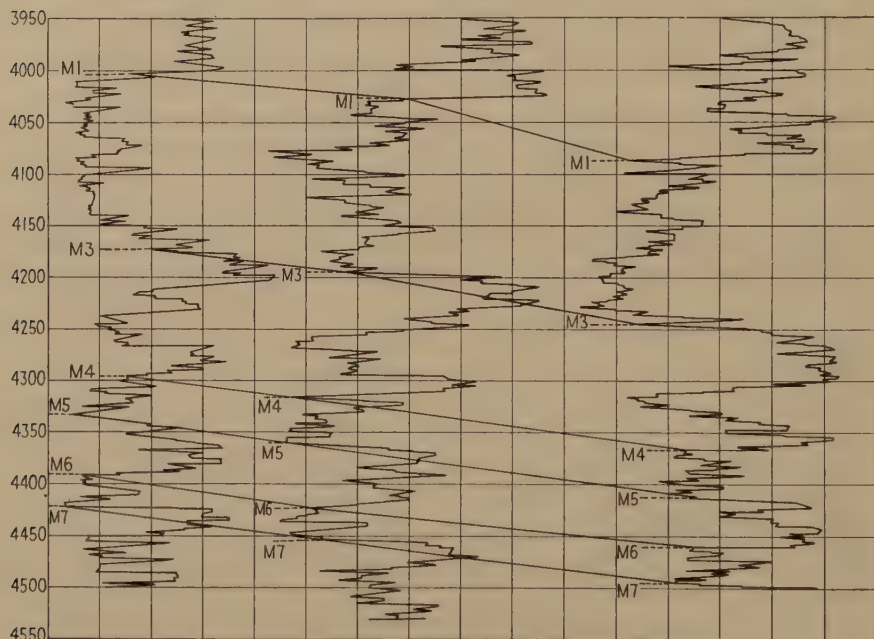


FIG. 1.—CORRELATION OF SANTA FE SPRINGS MARKERS.

is recognized and fairly well accepted, at least by a certain portion of the industry, that formations can be logged electrically in open holes. The new method developed in this experimental work is known as the "Stratagraph." Within the present year it has been used successfully at Santa Fe Springs (Fig. 1) to locate oil sands only 25 ft. thick, and at Ventura it has been used to locate a gas sand. As the ability to make the record and to interpret it grows, this device should be of great value in old fields where it is desired to shoot casing to secure oil sands that have been left behind the pipe.

The method is based upon the electromotive series of metals. Two circuits are established and nearly balanced against one another; the difference between the two making a record that is interpreted (Figs. 2,

3 and 4). Each of these circuits is so regulated with resistance that it has about the same strength as the other, their variations being affected by the electrical effect of the fluid in the formation, which serves as an

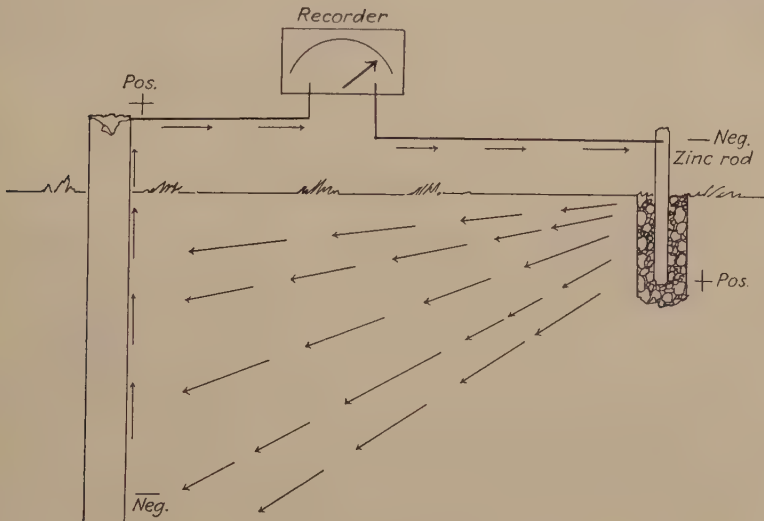


FIG. 2.—FIRST CIRCUIT.

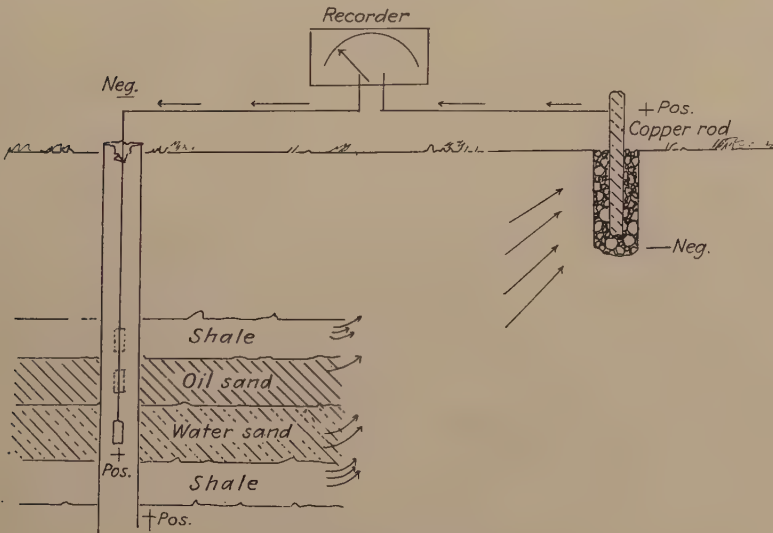


FIG. 3.—SECOND CIRCUIT.

electrolyte. The first circuit includes a zinc rod driven in the ground approximately 150 ft. from the well. The current flows from the zinc rod through the earth to the casing of the well and is returned to the zinc rod from the casing through a wire in which the recording instrument and the resistance are placed. The second circuit includes a zinc plate

suspended on an insulated wire line inside the casing. The fluid in the casing may be oil-field water, fresh water, salt water or mud, but of the same consistency. This creates a constant electrolytic action between the zinc plate and the casing. The current flows from the zinc to the casing and from the casing through the earth to a copper ground located approximately 100 ft. from the well. It returns from the copper ground

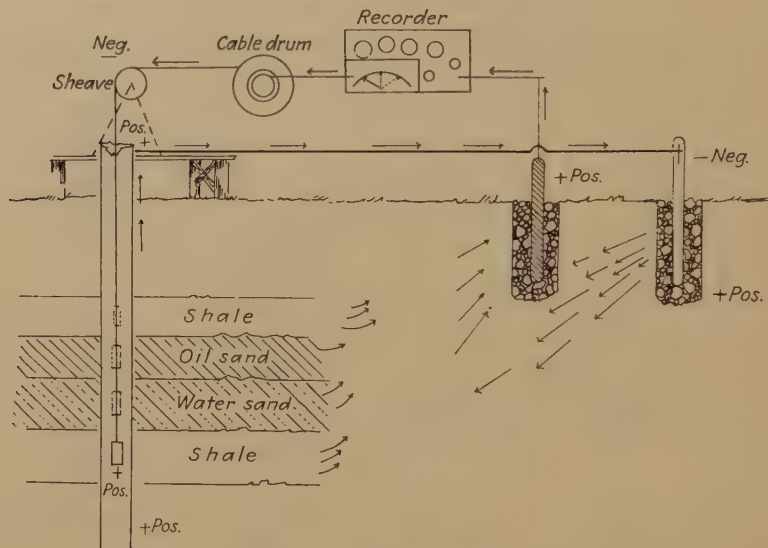


FIG. 4.—COMBINED CIRCUITS.

through the recording instrument and the resistance down the cable to the zinc plate. These two currents flow in opposite directions. The only purpose of introducing the resistance in one of the circuits is to limit the swing of the needle of the recording device to the width of the paper on which the record is made. As the suspended zinc plate is raised or lowered in the well, and comes opposite the different beds outside the casing containing fluids of different strength, currents of different magnitude are set up. Thus the record is made. Where the record swings widely to the left, it indicates shale and where it swings widely to the right, it indicates sand.

Chapter II. Production Engineering Research

Flow of Gas-liquid Mixtures through Sands

BY M. MUSKAT,* R. D. WYCKOFF,* H. G. BOTSET* AND M. W. MERES*

(New York Meeting, February, 1937)

THE subject of the flow of homogeneous fluids—gases alone or gas-free liquids—through porous media may be considered at the present time to be fairly well completed. That is, analytical, graphical, numerical, or experimental methods are now available for obtaining detailed descriptions of the behavior of such homogeneous fluid systems of any reasonable geometry. Thus, satisfactory empirical techniques are now well established for the determination of the permeability of porous media for homogeneous fluids, the numerical magnitude of this permeability uniquely and completely describing a porous medium as a carrier of a homogeneous fluid.

Considering this constant as known, the treatment of a wide variety of specific problems involving either the flow of gases or liquids has been carried through to satisfactory conclusions. Beginning with the simple case of strictly radial two-dimensional flow of a liquid or gas into a well under steady-state conditions, generalizations have been developed to apply for systems where the flow is not strictly radial, due either to a lack of uniformity in the reservoir pressures at points distant from the well or deviations from circularity of the external boundary whereby the fluid is being supplied, and finally, to the lack of complete penetration of the well into the producing strata. Satisfactory descriptions are now available for cases where gravity is acting as the driving agent inducing the flow of liquid into the well, either alone or as a supplement to the effect of pressure. The effect of acid treatment on limestone wells has been given a reasonable interpretation on the basis of the fundamental theory of the flow of homogeneous fluids through sands, as have the important features of the problem of water-coning. Then, too, systems in which the outlet of the fluid from the underground reservoir is of a predominantly multiple character may be now considered as in the domain of

This paper is a fusion and abbreviation of two separate papers published by R. D. Wyckoff and H. G. Botset, M. Muskat and M. W. Meres in *Physics* (1936) **7**, 325-345 and 346-363. Manuscript received at the office of the Institute Feb. 15, 1937.

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tractable homogeneous fluid flow problems which may be attacked by analytical methods, electrolytic conduction models, or metallic conduction experimental models. In particular, the theory of infinite groups of wells in line arrays and the mutual shielding and interference effects may be given an exact description. The associated problems of well offsetting with respect to lease boundaries are likewise amenable to treatment. Moreover, the particularly practical cases in which the multiple well systems are arranged in such regular arrays as are commonly used in water-flooding programs have been subjected to quantitative numerical analysis. Means are also available for extending the steady-state treatment of these problems to that of the transient state, in so far as these arise from the inherent compressibility of the liquid, such as has been carried through in detail in describing the history of the pressure decline of the East Texas field. Furthermore, these results have been made available for the discussion with a satisfactory degree of completeness of similar problems occurring in the production of gas from underground reservoirs. And finally this development of the subject of the flow of homogeneous fluids through porous media, which has to a large extent been accomplished by those engaged in activities of the petroleum industry, has even been extended to a certain degree to such related fields as hydrology and civil engineering. For now it is possible to discuss quantitatively such questions as the drainage of water-logged lands by tile drains, the seepage of water out of canals or ditches, the uplift pressures on dams with and without sheet piling, and the seepage flux through dams of arbitrary geometry.

Although a great many problems of practical petroleum production can be treated satisfactorily on the assumption that the fluid moving in the sand is homogeneous and essentially gas-free, and hence by such methods as used for the treatment of the problems mentioned above, it must be admitted that the extremely important problems of pressure and production decline, ultimate recovery, well spacing, and gas repressuring are definitely beyond the scope of the homogeneous fluid theory. In the discussion of these, the presence of gas in the reservoir pores cannot be ignored. Indeed it is only because of the gas that is originally dissolved in the oil and subsequently escapes and expands as the pressure is released that the oil production in profitable quantities can be obtained at all, except in the restricted class of water-drive fields exemplified by the East Texas oil field. In fact, the gas is the *sine qua non* of the oil production, since the expansion of the oil itself would be entirely negligible in producing volumes of oil of economic significance. And as we shall see later, the gas must actually be treated on an equal basis with the oil, so that a complete theory of the flow of the gas-oil mixture will involve a description of the flow of the gas phase that is just as detailed as that of the flow of the liquid phase.

It might be thought that one could synthesize theoretically a gas-liquid mixture system as the composite result of a combined flow of a homogeneous gas and a homogeneous liquid. If this were so it would indeed have been most fortunate, as it would have spared the authors three years of experimental and analytical effort spent in what at times seemed to be hopelessly futile attempts to obtain the results to be reported here. Moreover it would make unnecessary the extended program of research that is being conducted in the extension of the results obtained thus far with unconsolidated sands to the case of consolidated sands. That the resultant flow of a gas-liquid mixture is not simply an elementary combination of that of two separate phases flowing as homogeneous fluids is, of course, ultimately proved by experiment. However, one may readily convince himself of the unlikelihood that it would be so even without experimental tests, when one asks himself the question as to how to take account of the constant evolution of the gas from the liquid phase in terms of homogeneous fluids, and how to express the permeability of either phase when in the presence of the other.

THE EXPERIMENTAL PROBLEM AND THE TECHNIQUE USED IN ITS SOLUTION

Resigning then to the task of attacking the problem by direct experimental means, the first question that arises concerns the nature of the physical quantities that must be determined in order to give a complete description of the flow system. A little consideration shows that they are:

1. The liquid content or saturation of the sand which, of course, determines the free gas content.
2. The rate of flow of the liquid.
3. The rate of flow of the gas.
4. The pressure gradients inducing the flow.

In principle, at least, the determination of the pressure distribution in the sand is obviously the simplest, as it necessitates only providing the flow tube or sand column with a series of manometers or pressure-indicating devices appropriately distributed along the length of the flow system. Under conditions of steady-state flow—that is, when the pressures and velocities in the system have become constant and independent of the time—the rate of flow of the liquid is also easy to measure, as it is given by the rate of liquid efflux, which must necessarily be the rate of flow everywhere along the length of the column. The determination of the rate of gas flow, even under steady-state conditions, necessitates a simultaneous measurement of the liquid saturation distribution in the flow system. Thus if the latter is known as well as the pressure distribution, one can easily compute the gas velocity at any point in the system from that measured at the efflux terminal by taking into account the local liquid contents and pressures along the length of the flow column.

For obviously the free gas velocity at any point is simply that at the outflow end minus the quantity of gas that has been evolved between the point of interest and the efflux terminal.

The fundamentally new empirical element that must therefore be determined is the distribution of the liquid saturation or free gas content along the flow column. This was found by making the liquid supply conducting, and then by means of an alternating-current bridge measuring the increase in resistance of sections of the column due to the formation of free gas bubbles within the sand body. For it is clear that since the

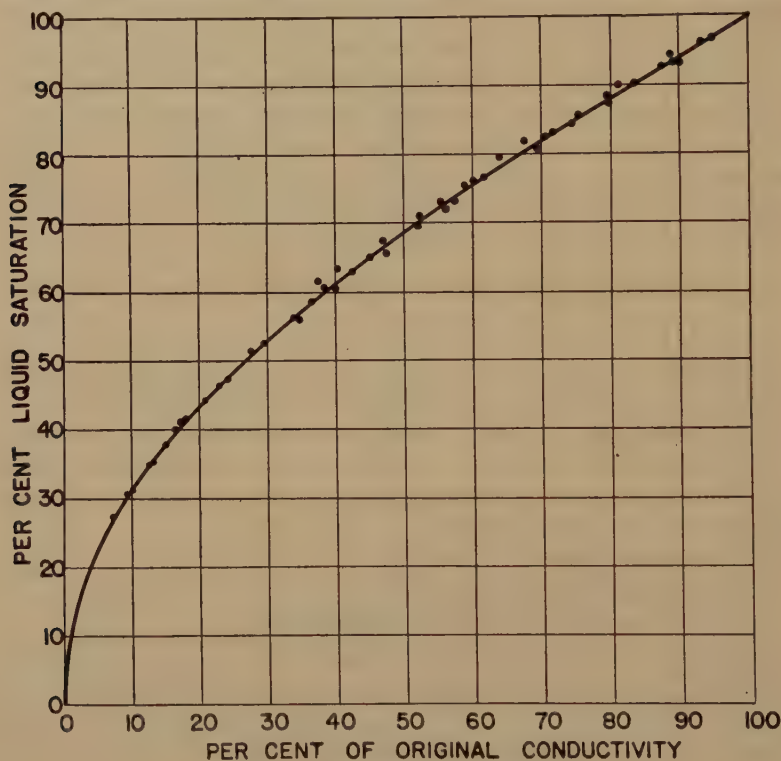


FIG. 1.—CALIBRATION CURVE.

gas is nonconducting the resistance of such a section of sand will increase as the conducting liquid is displaced and a larger fraction of the pores is occupied by the free gas. Of course, to make quantitative use of this principle calibration tests had to be made so as to give the exact relation between the conductivity of the sand and the free gas volume or liquid content. The calibration curve so found is shown in Fig. 1, where data are plotted which were obtained from three different unconsolidated sands varying in porosity from 27.76 to 42.97 per cent and from a consolidated Berea sandstone of 19.65 per cent porosity. The liquid used was water saturated with CO_2 . Within experimental error no differences

were observed between the various porous media, so that the results may be given a wide range of validity.

To apply this method of measuring liquid saturations or free gas contents to the actual flow experiments, it was necessary that the flow tube be provided with appropriately spaced electrodes for the conductivity measurements. These electrodes were combined with a pressure-measuring device in the form of piezometer rings, which gave pressures that actually represented the averages over the entire circumference of the sand column and avoided the difficulties and fluctuations resulting from the use of single-opening pressure tubes. The details of the piezom-

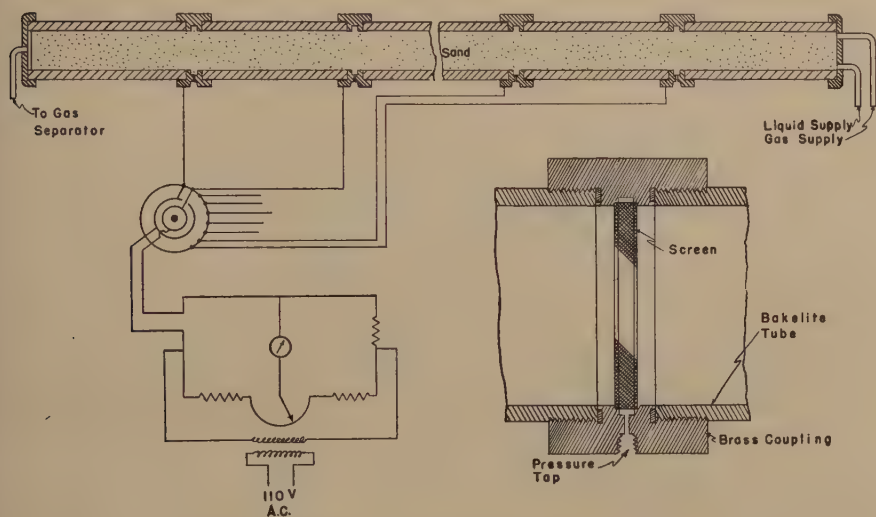


FIG. 2.—DETAILS OF PIEZOMETER RING COUPLING.

eter ring coupling are shown in Fig. 2. In order to be certain that the current flow was confined only to the conducting liquid, the electrode and piezometer rings were separated by Bakelite tubes forming the sections, which together constituted the flow tube. The complete assembly of apparatus is shown in Fig. 3, in which are indicated the manometers connected to the piezometer rings, the conducting leads from the latter to a Leeds & Northrup 60-cycle a.c. bridge, the inflow connections for the liquid and gas, and the outflow separator that permitted individual measurements of the liquid and gas effluxes. The mercury in the manometers was separated from the conducting flow liquid, which communicated with the flow tube by 5-cm. columns of dibutylphthalate. The composite flow tube of 10 sections had an over-all length of 10 ft., an inside diameter of 2 in., and was capable of withstanding 125 lb. pressure.

When standing vertically, the tube was carefully filled with known weights of sand of the desired grain size, previously wetted in distilled

water. Each addition of sand was tamped in place until homogeneity of the completed sand column was attained, this being tested after the flow tube was set into place by measuring the permeability of the individual sections. The porosity of the sand was determined from the known volume of the tube, the weight of the sand introduced, and its grain density. The tube was first filled with a gas-saturated liquid, the pressure being maintained above the saturation pressure of the gas so as to make sure that no free gas was released within the sand body, this condition being readily checked by the electrical resistance measurements. When a sufficient volume of liquid had been flushed through the tube to insure the elimination of any water or free gas originally present, the

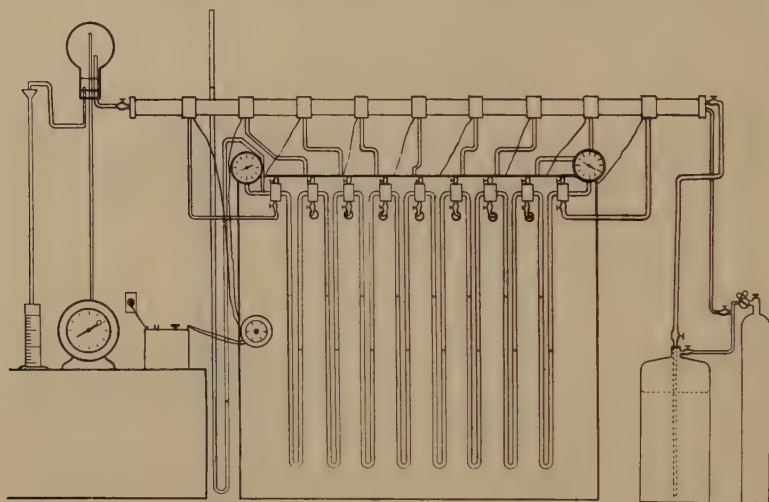


FIG. 3.—ASSEMBLY OF APPARATUS.

flow was carefully regulated for a constant rate and simultaneous measurements were made of the rate, pressure drop, and electrical resistance across each section of the tube. The auxiliary gas pressure on the supply tank was then reduced to a value just slightly above the saturation pressure of the liquid and the inflow and outflow needle valves on the sand column were adjusted so that the pressure within the flow tube was slightly below saturation pressure. A small amount of gas was then released continuously within the sand body and flowed through the system along with the liquid. When steady-state conditions were reached the rates of flow of gas and liquid and the resistances and pressures were measured simultaneously. This process of gradually decreasing the absolute pressure within the flow system so as to increase progressively the volume of free gas released within the sand was continued until the outflow section of the system reached atmospheric pressure. At this point, in order that

the ratio of the free gas to liquid might be increased beyond the solution ratio, an auxiliary gas inlet at the inflow end, feeding CO_2 from the supply tank, was opened to the flow tube. In this manner the gas-liquid ratio flowing through the system was varied from zero during the initial stage to very high values at the completion of a series of observations, such a series frequently requiring an entire week for the complete cycle.

EXPERIMENTAL RESULTS

A physically reasonable representation of the data obtained by the experiments described above may be derived by analogy with the corresponding problem in the study of homogeneous fluid systems. It will be recalled that the fundamental empirical result governing the whole subject of the viscous flow of homogeneous fluids is Darcy's law stating that the fluid velocity is directly proportional to the pressure gradient and inversely proportional to the fluid viscosity, the constant of proportionality being termed the permeability of the porous medium, and uniquely defining the latter from the hydrodynamic point of view. It is therefore natural to suppose that a heterogeneous fluid consisting of a mixture of gas and liquid phases will also be described by a law of proportionality between the fluid velocity and the pressure gradient. However, one must now distinguish between the fluid phases to which the velocity refers, that is, whether gas or liquid, and moreover the coefficient of proportionality cannot be expected to be a constant independent of the nature of the fluid mixture. Indeed, these may well be expected to depend upon the volume composition of the mixture, the variability of which is really the significant feature giving rise to the fundamental difference between the problems of the flow of homogeneous and heterogeneous fluids through porous media. For if the volume composition of the mixture were the same at all points of the medium, it would only be necessary to change the effective permeability and porosity of the medium for either component to reduce the problem to that of the flow of homogeneous fluids, as can actually be done in the treatment of the steady-state flow of two immiscible liquids.

Hence, expressing the volume composition of the mixture by the liquid saturation of the medium, ρ —the part of the pore volume instantaneously occupied by the liquid—it is clear that this same saturation will also determine the effective permeability of the medium for either component of the mixture. For if we now denote by the permeability the macroscopic velocities of the individual fluid phases in the mixture per unit pressure gradient, it is apparent that the permeability for either the gas or liquid phase will increase as the fractional volume of the pores occupied by either increases. Thus when the medium is completely saturated with liquid the gas permeability will be zero, since no free gas phase is actually being transmitted through the medium. Likewise, when there

is no liquid phase present the liquid permeability will be zero, as no liquid is being produced even though the medium is subjected to a nonvanishing pressure differential. Moreover, these local liquid saturations will change from point to point in the system as the pressure varies. It follows that the porous medium itself must be considered as changing from point to point, and can therefore no longer be defined by a single invariable permeability. Rather one must generalize this concept, which is based upon the assumption that all the interconnected pores of the medium are filled

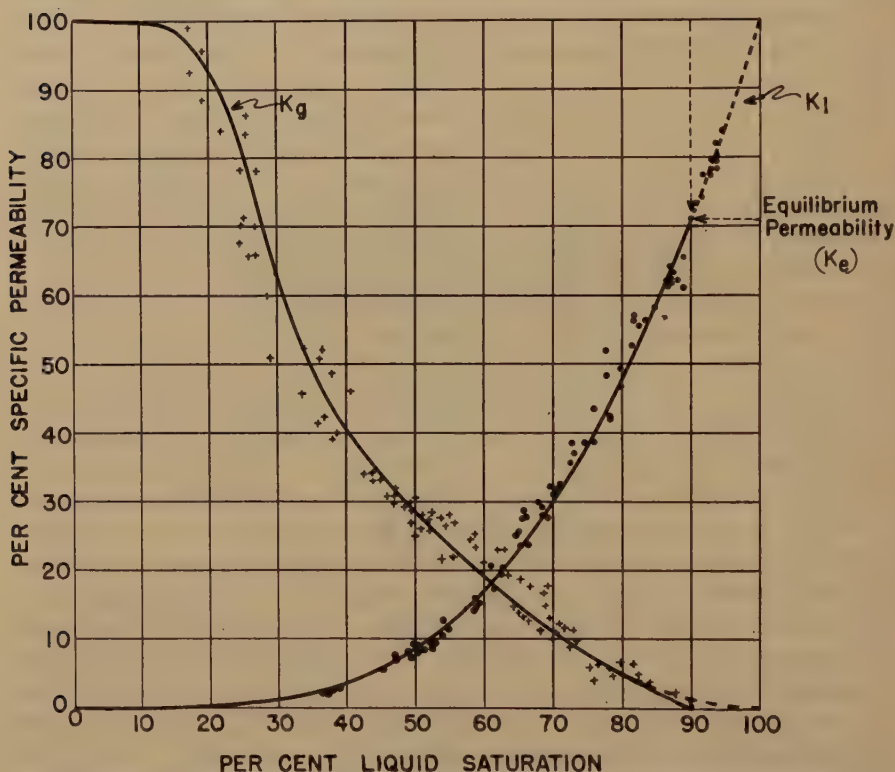


FIG. 4.—RELATION BETWEEN GAS AND LIQUID PERMEABILITIES AND LIQUID SATURATIONS.

by the fluid it is bearing, and assign to the medium a *local* structure defined by the local saturation, the latter in turn uniquely determining the local permeabilities for both the gas and liquid phases of the mixture.

These considerations clearly lead to the result that the fundamental empirical element to be deduced from such gas-liquid mixture experiments as described above is the relation between the permeabilities of the gas and liquid phases and the volume composition of the mixture, or the liquid saturation. These relations being given, all the necessary elements for formulating mathematically the hydrodynamics of heterogeneous

fluid systems analogous to that of homogeneous fluid systems will be available. It is therefore natural to express the results of the experiments in the form of curves relating the gas and liquid permeabilities to the liquid saturations. Such a pair of curves, obtained with a 70 to 120-mesh sand having a homogeneous fluid permeability of 17.8 darcys, is shown in Fig. 4, the permeabilities being expressed as percentages of the homogeneous fluid values and the saturation as percentages of the total pore

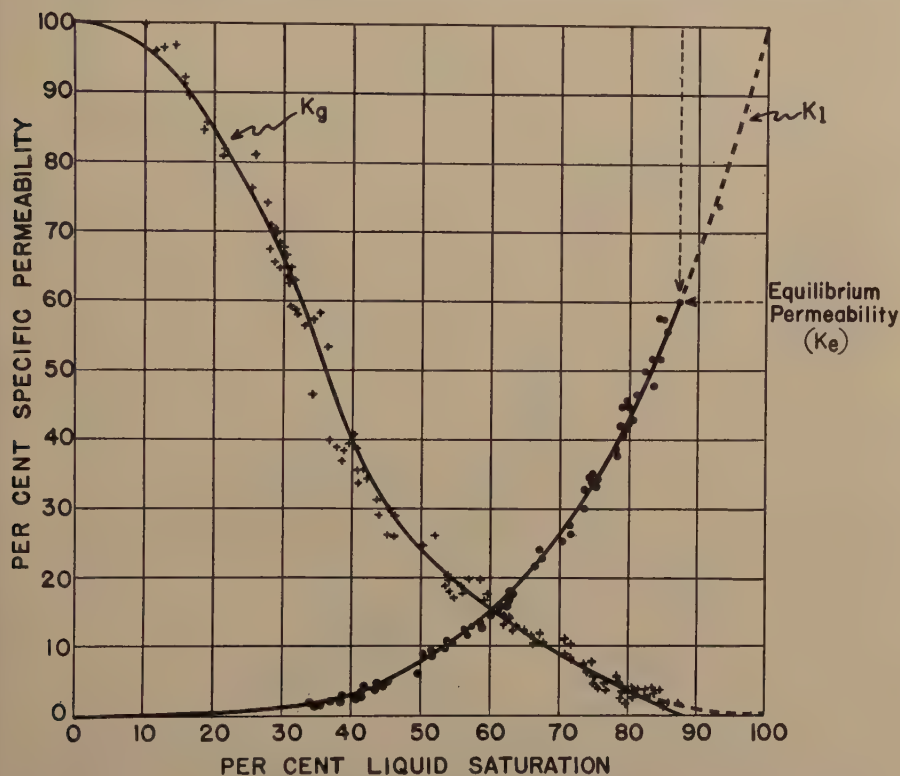


FIG. 5.—RELATION BETWEEN GAS AND LIQUID PERMEABILITIES AND LIQUID SATURATIONS.

content. A similar pair of curves obtained with heterogeneous sand having a normal permeability of 44.3 darcys is given in Fig. 5. In fact, experiments with still other sands show that for practical purposes the curves for the permeabilities k_g and k_l may be considered to be independent of the nature of the unconsolidated sand, as is shown by Fig. 6, in which the permeability-saturation data are shown for four different sands including the two of Figs. 4 and 5. Moreover, further experiments have shown that these curves are not materially changed by variations in the viscosity of the liquid, by using sugar and water solutions of 3.4 centipoises viscosity, nor by variations in surface tension, as found in tests on water-alcohol solutions of 27 dyne cm. surface tension.

DIRECT IMPLICATIONS OF THE EXPERIMENTAL DATA

Although one may anticipate that if the accuracy of the experiments were materially increased variations of the curves with the fluid viscosities and interfacial tension would actually be found, it seems certain that the principal features of the permeability vs. saturation curves shown in Figs. 4 to 6 are fundamental characteristics of gas-liquid mixtures. These principal features are:

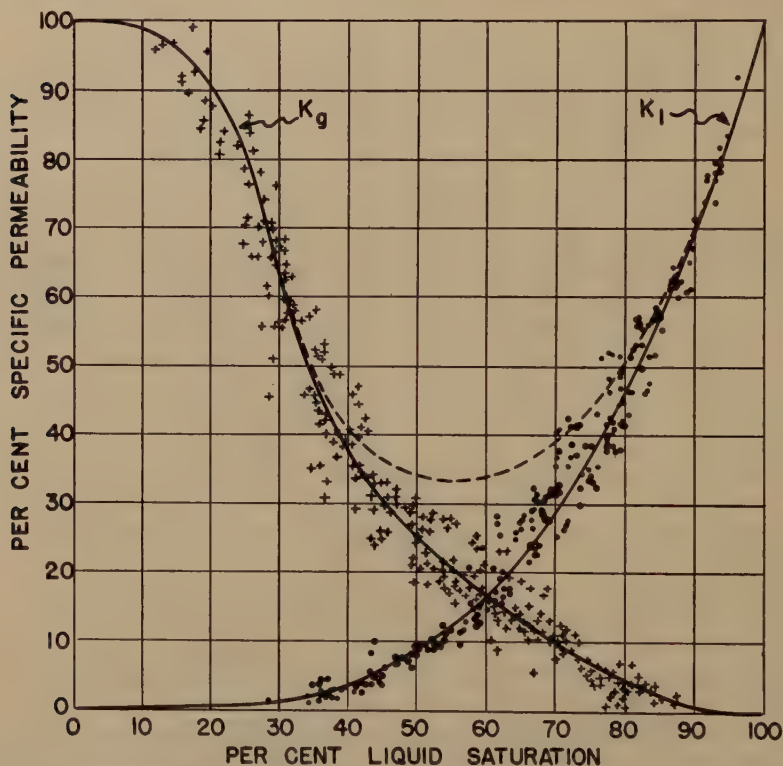


FIG. 6.—PERMEABILITY-SATURATION DATA FOR FOUR DIFFERENT SANDS, INCLUDING THOSE OF FIGS. 4 AND 5.

1. The sharp drop in the liquid permeability and the very slow rise in gas permeability for small amounts of free gas dispersed through the sand.
2. The attainment of an almost complete homogeneous fluid permeability for the gas even with the presence of 10 to 20 per cent of liquid within the pores of the sand.
3. The property that for a given sand steady-state conditions cannot be maintained until the gas saturation has built up to a certain minimal value, thus indicating an effective locking of free gas in the pores until

enough is accumulated so that further additions will be flushed out by the flowing fluids.

The first feature leads to a rapid drop in the sum of the liquid and gas permeabilities below the normal or homogeneous fluid permeability as free gas develops in the pores. This fact immediately shows that the interaction of the two fluid phases is an important part of the dynamics of the system. For if they moved entirely independently it would, of course, be expected that the sum of the gas and liquid permeabilities should simply equal the normal fluid values, and that the curve for each should be a diagonal across the diagrams of Figs. 4 to 6. Moreover, it shows that there is considerable energy dissipation in the system in addition to that caused by the direct viscous friction. As similar experiments with oil flowing through water-wet sand have given the same type of permeability curve for the oil, it follows that these energy losses are not due simply to the elastic vibrations of the gas bubbles. Rather, one must attribute them to the composite effect of the friction losses in the local eddies in the liquid resulting from the continuous forming and breaking of the interfaces between the gas and liquid phases and the transient Jamin effect exerted by a part of the flowing gas. As already anticipated above, this one fact alone proves that the synthesis of a gas-liquid mixture system as a simple combination of two homogeneous fluid phases would be but a very poor approximation.

The fact that the gas permeability attains almost 100 per cent of its normal homogeneous fluid value even when some 20 per cent of the sand pores are occupied by liquid may also be given a direct physical interpretation. For it simply shows that the remaining portion of the liquid must not appreciably interfere with the flow of the gas. An immediate inference from this is obviously that the liquid present in the pores under such conditions of flow is localized about the contacts between the sand grains and in the sharp-angled parts of the pores, which even in a homogeneous fluid system probably contribute but little to the total fluid flux. That is, these small percentages of liquid are retained in the effectively dead spaces of the system and affect only slightly the main course of the flow.

A consideration of the gas-liquid ratios in the gas-liquid mixture systems throws further light on these features of the flow. Thus from the definition of the gas and liquid permeabilities it follows at once that except for the constant factor involving the fluid viscosities the ratio k_g/k_l gives effectively the gas-liquid ratio through the system. Using the average curves of Fig. 6 this ratio is plotted against the liquid saturation in Fig. 7. Here the two features discussed above are shown in an even more striking manner. Thus the very low gas permeabilities for small free gas contents give extremely low values of the gas-liquid ratio at high liquid saturations, and the rapid rise of the gas permeability

together with the negligible interference caused by the entrained liquid leads to extremely high gas-liquid ratios for small liquid saturations.

Before discussing some of the further implications of this gas-liquid ratio curve, it is well to consider the last salient feature of the individual gas and liquid permeability curves mentioned above. For the experi-

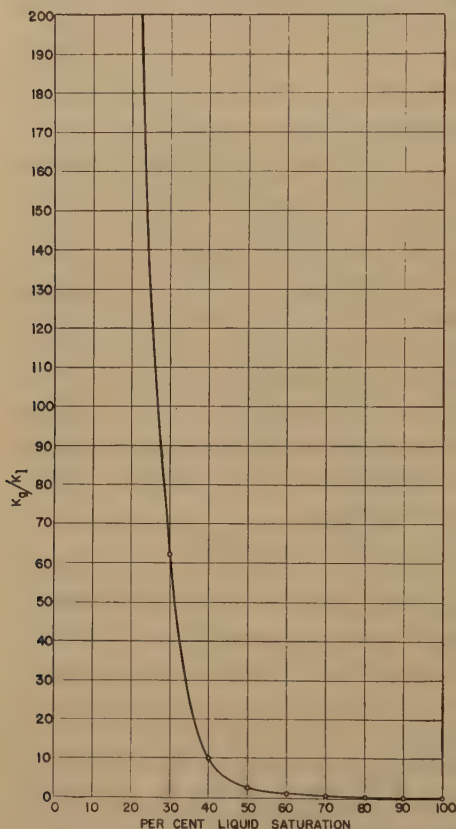


FIG. 7.—RELATION OF GAS-LIQUID RATIO TO LIQUID SATURATION.

ments have shown it to be an empirical fact that it is impossible to maintain steady-state conditions for any arbitrarily high value of the liquid saturation. On the contrary, it is found that even if the gas-liquid ratio flowing through the system should be extremely small, and if one begins with complete or very high liquid saturations, the liquid will be gradually displaced and gas will accumulate until at least a certain minimum fraction of the pore content is filled before the flow conditions become steady. The permeability at this limiting saturation has been termed the "equilibrium permeability," and the saturation as the "equilibrium saturation." If, by increasing the flow of gas, the saturation is reduced below the equilibrium value, the permeabilities will slide down along the curves shown to some new equilibrium value where steady-state conditions will be automatically established. And conversely if one begins with the state of flow where the liquid saturation is lower than the equilibrium value, and the gas flow is decreased, the permeabilities and saturation will slide upward along the curves. However, it has been found that flow systems having liquid saturations above the equilibrium value cannot be maintained permanently in stable conditions. When the system begins from a very high or complete liquid saturation the continuous accumulation of free gas volume obviously corresponds to an effective locking of at least part of the flowing gas within the pores and displacement of the liquid until enough is accumulated to lead to a flushing action of the gas. Although it has not yet been possible to develop

the state of flow where the liquid saturation is lower than the equilibrium value, and the gas flow is decreased, the permeabilities and saturation will slide upward along the curves. However, it has been found that flow systems having liquid saturations above the equilibrium value cannot be maintained permanently in stable conditions. When the system begins from a very high or complete liquid saturation the continuous accumulation of free gas volume obviously corresponds to an effective locking of at least part of the flowing gas within the pores and displacement of the liquid until enough is accumulated to lead to a flushing action of the gas. Although it has not yet been possible to develop

a quantitative explanation of this behavior, it must be recognized as one of the most characteristic properties of the dynamics of gas-liquid mixture flow. The magnitude of the equilibrium permeability, of course, varies with the nature of the sand and somewhat with the character of the fluids. However, there appears to be a distinct correlation between these equilibrium permeabilities and the normal homogeneous permeability as shown in Fig. 8, so that a determination of the latter permits at least an approximate prediction of the equilibrium conditions when mixtures are flowing through the sand.

While this rather peculiar behavior, in which gas-liquid mixtures with low gas-liquid ratios automatically tend to attain equilibrium conditions

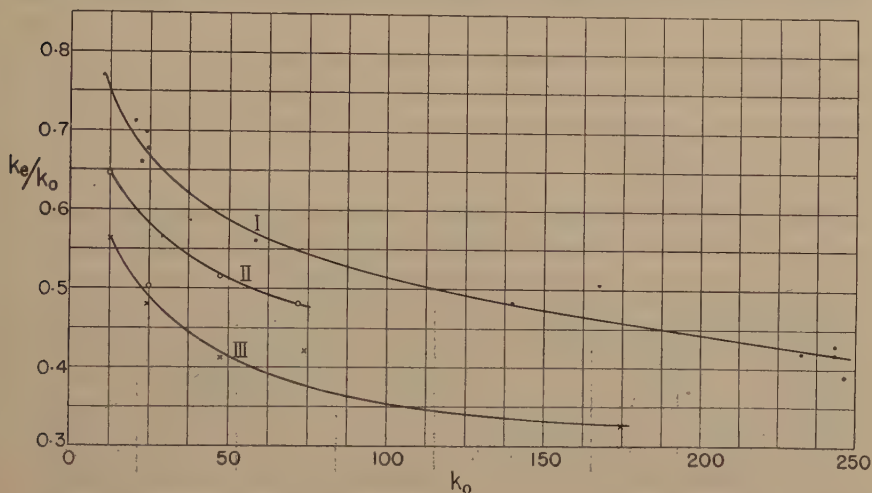


FIG. 8.—EQUILIBRIUM (k_e) VS. NORMAL HOMOGENEOUS PERMEABILITY (k_0).

by the accumulation of free gas in the pores of the sand, may appear at first thought to be only of academic interest, actually it represents one of the most fundamental properties of the gas-liquid mixture systems from a practical point of view. For it is clear that whatever the experimental results might have been it is just the region of high liquid saturations that corresponds to the practical field conditions of oil production, since we know that the recoveries in the latter are usually limited to 20 to 35 per cent. The specific result that transient states cannot be maintained above the equilibrium conditions therefore implies that a sand containing a liquid saturated with gas will, upon the lowering of the liquid pressure, automatically tend to expel enough of its liquid until the liquid saturation will have fallen to at least the equilibrium value. In other words, there is a definite tendency in such systems for the production of *at least a minimum* amount of the liquid as long as the gas content is not too small. For the unconsolidated sands used in these experiments

this limiting gas content corresponds to a gas-liquid ratio of the order of 10 c.c. per c.c. Hence as long as this gas content is exceeded, one may expect that the liquid recovery from an unconsolidated sand body upon release of pressure will everywhere reach at least a certain minimum value, defined only by the equilibrium saturation and quite independent of the rate of the release of the pressure or the geometry of the flow system.

That this deduction from the fundamental flow experiments has real validity is verified by actual tests on the total production obtained from columns of various unconsolidated sands filled with gas-saturated liquids when simply allowed to produce by release of pressure at one end. The results are shown in Table 1, showing that within the limits of experimental error the total production does correspond to the equilibrium saturation previously obtained by direct flow experiments. Moreover, the tests with the 30 to 100-mesh sand at different saturation pressures and gas-liquid ratios show that as long as the ratio exceeds the value of the order of 10, the recovery is largely independent of this ratio and has the minimum equilibrium value.

TABLE 1.—*Experiments on Fluid Production from Different Sands at Flow Rates Comparable with Those Encountered at Reasonable Distances from Producing Wells*

Grain Size	k_0	Q_l	v_l	Q_g	R	Per ρ_l Cent	Per ρ_e Cent
20-30	261	144	9.18×10^{-5}	3250	22.6	78.0	78 -80
40-60	59.4	119	7.04×10^{-5}	2410	20.2	87.7	84.5-86.2
70-120	16.1	87	5.60×10^{-5}	2440	28.0	89.8	90.5
30-100	45.9	114		2800	24.6	84.8	85.4-87.2
30-100	45.9	117		1400	12.0	83.9	85.4-87.2
30-100	45.9	84		700	8.3	88.8	85.4-87.2

k_0 = homogeneous fluid permeability in darcys.

Q_l = volume liquid produced.

v_l = average liquid velocity (c.c. per sq. cm. per sec.).

Q_g = volume gas produced (c.c.).

R = gas-liquid ratio (c.c. per c.c.).

ρ per cent = saturation (production experiment).

ρ_e per cent = equilibrium saturation (from curves of Figs. 6 and 8).

Although the production of the minimum ultimate recovery seems to result from a process that is practically independent of the production methods, it is not to be concluded that the total ultimate recovery from a sand is also entirely beyond the control of the operator. For if one increases the gas-liquid ratio and enters the region where steady-state conditions of flow are possible, one can, of course, attain in principle any arbitrary degree of liquid depletion. However, from a practical point of view the power of the operator to change materially the recovery is

still rather limited. Thus returning to Fig. 7, showing the gas-liquid ratios as a function of the liquid saturation, it will be noted that states of flow with liquid saturations less than 40 to 50 per cent require extremely high gas-liquid ratios. In fact, if the liquid saturation is to be pushed below 25 to 30 per cent, the necessary gas velocities will be so tremendous that the major part of the further depletion of the liquid will probably result from evaporation rather than from direct mass flow. Since the efficiency of production is inversely proportional to the gas-liquid ratio, it follows that the efficiency will decrease very rapidly as attempts are made to increase the recovery to exceed appreciably that given by the minimum equilibrium conditions. Applying these considerations to the problem of secondary recovery by gas injection, it becomes clear that the efficiency of such methods cannot be expected to be high except when the gas can be injected into gas caps or other structurally favorable parts of the reservoir, where it can exert a pistonlike effect upon the liquid and not simply channel through as the gas phase of a gas-liquid mixture system.

It should be emphasized that all the results discussed thus far as well as those to follow are based explicitly upon experiments performed with unconsolidated sands. While it is doubtful whether entirely new features will appear when the experiments are extended to consolidated sands, one must anticipate changes in the quantitative phases of the empirical data that may well have considerable effect upon the practical implications such as we have drawn here. Thus, for example, it is not inconceivable that the equilibrium saturation for typical consolidated sands might be as high as 90 per cent, so that more than half of the actual ultimate recoveries from oil-producing reservoirs may be the result of flow conditions that are definitely below the minimum equilibrium range. Under such circumstances, of course, the manner of production will play a far more important role than might be inferred from the experiments with unconsolidated high-permeability sands.

ANALYTICAL FORMULATION OF THE HYDRODYNAMICS OF HETEROGENEOUS FLUIDS

Although we have seen that a number of deductions of practical importance can be derived directly from the original experiments with linear flow columns, their application in a quantitative manner to systems of different geometry and such as correspond more closely to practical field operations requires an analytical formulation of the results. Unfortunately, the development of explicit numerical results from such a formulation is an extremely difficult problem, and even for systems of simple geometry it requires a very laborious and extended numerical program. However, as many of the important practical problems of oil production can be answered only by such analytical deductions from

the elementary basic experiments, we shall briefly outline the nature of the results thus far obtained by analytical means.

A little consideration will show that the necessary and sufficient elements involved in the formulation of the hydrodynamics of heterogeneous or gas-liquid mixture systems are the following:

1. A statement of the viscosities μ_g , μ_l of the gas and liquid phases, together with their dependence, if any of importance, on the pressure and other variables.

2. A statement of the solubility s of the gas in the liquid, and its "equation of state" in the forms:

$$S = sp; \quad \gamma = cp \quad [1]$$

where S is the mass of gas dissolved in unit volume of the liquid, and γ is the density at the pressure p . These assume, of course, that the gas obeys the ideal gas laws as well as Henry's law. However, their equivalent equations taking into account deviations should, of course, be used when these deviations are significant.

3. The "laws of flow" for the gas and liquid phases, as:

$$\bar{v}_g = -(k_g/\mu_g)\nabla p; \quad \bar{v}_l = -(k_l/\mu_l)\nabla p \quad [2]$$

where $\bar{v}_l$, $\bar{v}_g$ are the macroscopic vector velocities—volume fluxes per unit area of the medium—of the liquid and free gas phases, μ_l , μ_g are their viscosities, and k_l , k_g are the permeabilities to the liquid and gas.

4. The empirical relation between the gas and liquid permeabilities and the liquid saturation ρ , as:

$$k_g = k_0 F_g(\rho); \quad k_l = k_0 F_l(\rho), \quad [3]$$

where k_0 is the homogeneous fluid permeability and ρ is the actual liquid saturation divided by the normal porosity f .

5. The equations of continuity for both the gas and liquid, which are:

$$\left. \begin{aligned} \nabla \cdot (\gamma \bar{v}_g) + \nabla \cdot (S \bar{v}_l) &= -f(\partial/\partial t)\{S\rho + \gamma(1 - \rho)\} \\ \text{and} \quad \nabla \cdot \bar{v}_l &= -f\partial\rho/\partial t \end{aligned} \right\} \quad [4]$$

Combining these, we finally obtain for systems of uniform homogeneous fluid permeability:

$$\left. \begin{aligned} \frac{c}{\mu_g} \nabla \cdot \{p F_g(\rho) \nabla p\} + \frac{s}{\mu_l} \nabla \cdot \{p F_l(\rho) \nabla p\} &= \frac{f}{k_0} \frac{\partial}{\partial t} p \{s\rho + c(1 - \rho)\} \\ \nabla \cdot \{F_l(\rho) \nabla p\} &= \frac{f \mu_l}{k_0} \frac{\partial \rho}{\partial t} \end{aligned} \right\} \quad [5]$$

in the two variables ρ and p , μ_l , μ_g , s and c having been taken as constants.

These represent the fundamental equations which will govern the flow of heterogeneous fluids through porous media. As already indicated, the functions $F_g(\rho)$ and $F_l(\rho)$ must be predetermined empirically by such means as were described in the first part of this paper, and are to be considered as physical data to be provided together with the quantities c, s, f, μ_g, μ_l before any numerical analysis of a particular flow problem can be attempted.

SOME STEADY-STATE SOLUTIONS

For the conditions of the steady-state, analytical solutions of these equations can be derived for the cases of radial, linear and spherical flow.

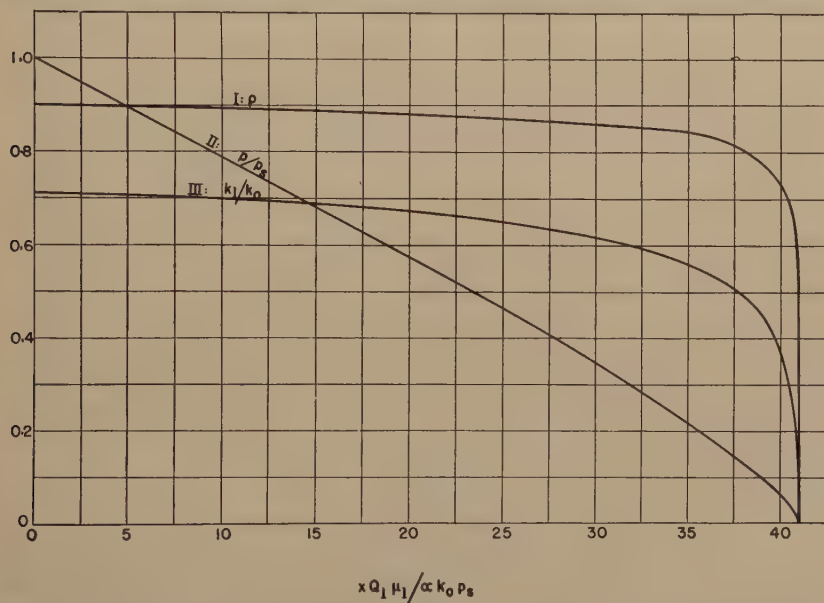


FIG. 9.—STEADY-STATE DISTRIBUTIONS OF ρ , k_l AND p IN A LINEAR SYSTEM.

Thus for the case of linear flow, the saturation distribution can be shown to be determined by the equation:

$$x(\rho) = -\frac{Rk_0\mu_g}{\mu_l^2 Q_l} \int_{\rho}^{\rho_i} \frac{F_l(\rho) d\rho}{[\Psi(\rho) + \alpha]^2} \quad [6]$$

where the saturation at $x = 0$ is ρ_i , Q_l is the liquid flux through the system, and $R = Q_g/Q_l$, which is the gas-liquid volume ratio of the flux, as measured at atmospheric pressure, Q_g being the total volume gas flux through the system; $\Psi(\rho) = F_g(\rho)/F_l(\rho)$, and $\alpha = s\mu_g/c\mu_l$.

Knowing the saturation distribution, that is, ρ as the function of x , the permeability distribution can be immediately derived by applying

equations 3 or by using directly the original permeability vs. saturation curves as shown in Figs. 4 to 6. The pressure distribution can then be obtained by using the easily derived relation:

$$p = (R\mu_g/\mu_l)/(\Psi(\rho) + \alpha) \quad [7]$$

Applying this procedure to the empirical data for water-carbon dioxide mixtures for which:

$$\begin{aligned} s/c &= 0.88 \text{ c.c./c.c./atmos} \\ \mu_l/\mu_g &= 59.3; \quad \alpha = 0.0148. \end{aligned} \quad [8]$$

and for $F_l(\rho)$ and $F_g(\rho)$ the curves of Fig. 4, distributions of ρ , k_i and p are obtained such as shown in Fig. 9.

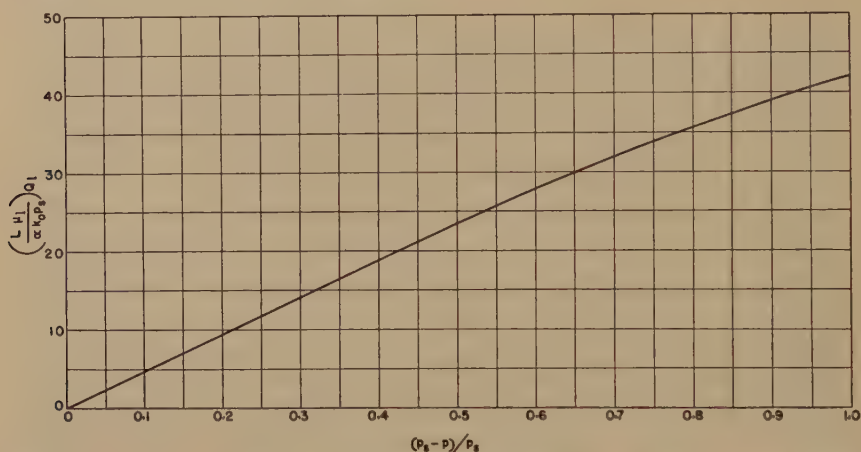


FIG. 10.—RELATION OF FLUX TO PRESSURE DIFFERENTIAL IN A STEADY-STATE LINEAR SYSTEM.

It will be seen from this figure that the saturation remains quite uniform and the pressure closely linear until the abscissa $xQ_l\mu_l/\alpha k_0 p_s$ exceeds the value 20. In this range therefore the flow approximates that of a homogeneous fluid, although the effective average permeability for the liquid is only 70 per cent of the homogeneous fluid permeability. If, however, the output pressure is kept effectively at zero so as to include regions where the saturations and permeability have fallen appreciably below their equilibrium values, the over-all average permeability of the flow system will be only 61 per cent of the homogeneous fluid permeability.

Translating these results in terms of the flux Q_l as a function of the pressure differential, gives the curve of Fig. 10. Here too the flux increases almost exactly linearly with the pressure differential until the outflow pressure has fallen to less than half of the saturation pressure, beyond which the decreasing permeability near the outflow end cuts down the flux so that it increases less rapidly than the pressure differential.

These results may be extended to systems in radial and spherical flow, the formulas for the saturation distribution being given by:

$$\text{Radial flow:} \quad \log \frac{r_e}{r} = \frac{2\pi h k_0 \alpha p_s}{Q_i \mu_i} \int_{\rho}^{\rho_e} \frac{F_i(\rho) \frac{d\Psi}{d\rho}}{[\Psi(\rho) + \alpha]^2} d\rho \quad [9]$$

$$\text{Spherical flow:} \quad \frac{1}{r} - \frac{1}{r_e} = \frac{4\pi k_0 \alpha p_s}{Q_i \mu_i} \int_{\rho}^{\rho_e} \frac{F_i(\rho) \frac{d\Psi}{d\rho}}{[\Psi(\rho) + \alpha]^2} d\rho \quad [10]$$

where ρ_e is the equilibrium saturation at the boundary $r = r_e$ where the pressure has the saturation value p_s . The saturation permeability and pressure distributions for the radial system analogous to those given in

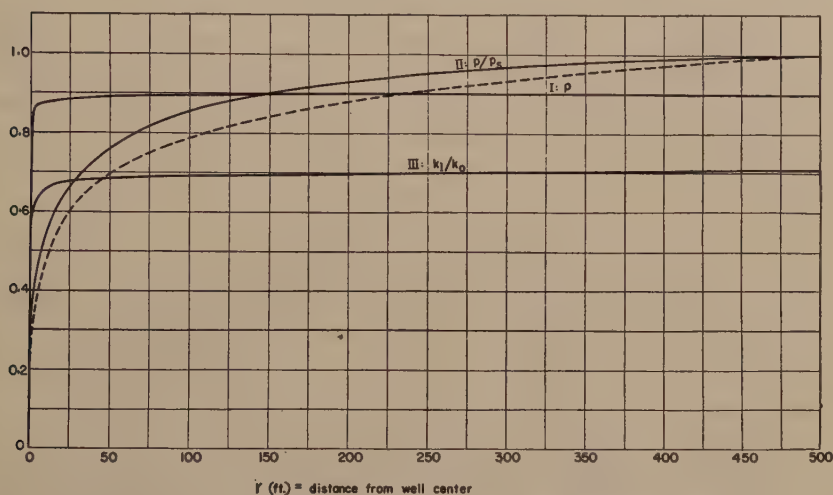


FIG. 11.—SATURATION, PERMEABILITY AND PRESSURE DISTRIBUTIONS FOR RADIAL SYSTEM.

Fig. 9 for the linear system, are shown in Fig. 11, the ratio of external boundary to well radius being taken as 2000. Here should be noted the extreme localizations about the well center of the drops in the saturation and permeability below their equilibrium values. However, although the highly localized saturation variation means only an extremely small change in the total liquid volume content of the sand from that in a uniformly saturated (to equilibrium value) sand, the drop in the permeability near the well does result in an appreciable increase in the concentration of the pressure gradients about the well center. This will be clear on comparing the heterogeneous fluid-pressure distribution indicated by curve II with that for a homogeneous fluid system given by the dotted curve.

The variation of the flux in radial and spherical systems with the pressure differential will be identical with that shown in Fig. 10 for the

linear case provided only that one interprets the ordinates of the latter to be:

$$\frac{\mu_l \log r_e/r_w}{2\pi h k_0 \alpha p_s} Q_l, \quad \text{and} \quad \frac{\mu_l (1/r_w - 1/r_e)}{4\pi k_0 \alpha p_s} Q_l$$

for the cases of radial and spherical flow, respectively. Thus for a fixed pressure differential $((p_s - p)/p_s)$, the flux Q_l will vary with the geometrical dimensions h , r_e , r_w of these heterogeneous fluid systems in exactly the same manner as does that in the corresponding homogeneous fluid system.

HISTORY OF THE PRESSURE DECLINE IN A LINEAR RESERVOIR

When one leaves the domain of steady-state conditions of flow and begins to consider the problem of transients it is quickly found that analytic solutions are no longer possible. Rather one must resort to numerical methods of solution. That no other recourse is available becomes clear when one notes that even for the simple case of linear flow the differential equations to be solved have the nonlinear complex form given by:

$$\begin{aligned} \frac{\partial p}{\partial \bar{t}} &= F_l \frac{\partial^2 p}{\partial \bar{x}^2} + \frac{\partial F_l}{\partial \bar{x}} \frac{\partial p}{\partial \bar{x}} \\ \left\{ \frac{c}{s} + \left(1 - \frac{c}{s} \right) \rho \right\} \frac{\partial p}{\partial \bar{t}} &= p \left\{ \frac{c}{s} \frac{\partial p}{\partial \bar{t}} + \frac{F_g}{\alpha} \frac{\partial^2 p}{\partial \bar{x}^2} \right\} + \frac{1}{\alpha} \frac{\partial F_g}{\partial \bar{x}} \frac{\partial p}{\partial \bar{x}} + \\ &\quad \left(\frac{F_g}{\alpha} + F_l \right) \left(\frac{\partial p}{\partial \bar{x}} \right)^2 \end{aligned} \quad [11]$$

where $\bar{x}$ and $\bar{t}$ are the dimensionless variables:

$$\bar{x} = x/L; \quad \bar{t} = k_0 t / f \mu_l L^2 \quad [12]$$

L being the length of the system, and the pressure being measured relative to a unit pressure that is supposed to be multiplied in the right side of the equation for $\bar{t}$.

In order, however, to give some indication of the implications of the experimental results described above with regard to the practical problem of pressure and production decline of an actual oil reservoir, a numerical stepwise solution was obtained for the simple case of a uniform linear column initially filled with liquid saturated to a pressure of one unit, and subsequently opened at one end to $1/10$ unit pressure. s/c was taken as 1 and α as 0.01. The results of this calculation are as follows: The history of the pressure decline throughout the system is shown by the curves in Fig. 12. Little need be said about these curves, as they are obviously what would have been expected from elementary considerations.

The production decline from the system, shown in Fig. 13, is also devoid of features that might not have been anticipated without any

detailed calculations. The situation, however, is quite different when one considers the history of the saturation distribution or liquid depletion, shown in Fig. 14. Here the distribution during the early stages of the production history is indeed of the nature that one might intuitively have anticipated from general physical arguments. For, as Fig. 14 shows, the saturation near the outflow surface drops rapidly as the pressure is released and the depletion wave travels only slowly to the distant parts of the sand. However, when one follows through the history of the pro-

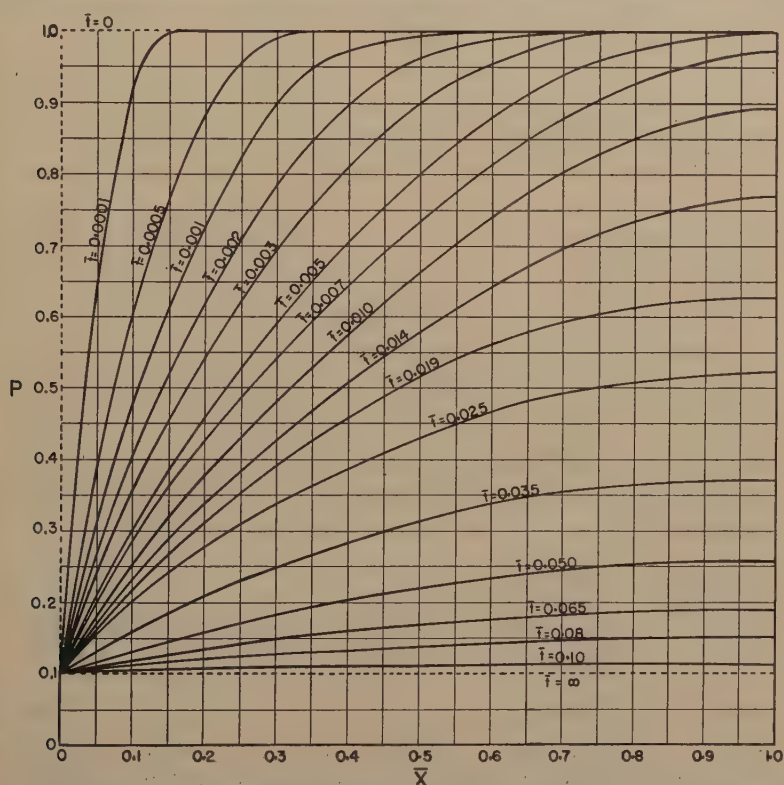


FIG. 12.—HISTORY OF PRESSURE DECLINE IN LINEAR CHANNEL WITH ONE TERMINAL CLOSED AND THE OTHER OPENED TO PRODUCTION.

duction to its later stages one finds that the growth of the depletion near the outflow surface has practically died down, whereas that in the distant parts of the sand has reached significant magnitudes. In fact, when the stage of complete physical depletion is reached, that is, when the pressure has everywhere fallen to the outflow value, the saturation at the most distant point in the sand is only 5 per cent higher than that at the outflow face.

To see what this means in more practical terms we may suppose that the sand column is 300 ft. long, has a porosity of 20 per cent, a permeability

of 100 millidarcys, and is originally filled with a liquid of 10 centipoise viscosity saturated with gas to a pressure of 10 atmospheres. Then it is found that after two days of production the pressure has dropped appreciably only within the first 45 ft. of the outflow face, the saturation has dropped to 81 per cent at the outflow face, but is still approximately 100 per cent beyond a distance of 60 ft., and the production rate has a value of 0.01 bbl. per day per sq. ft. of sand. After 97 days the wave of pressure drop has just reached the closed end of the column at 300 ft., the liquid saturation at the outflow face has fallen to 73.5 per cent and even that at the distant closed face has dropped somewhat, namely,

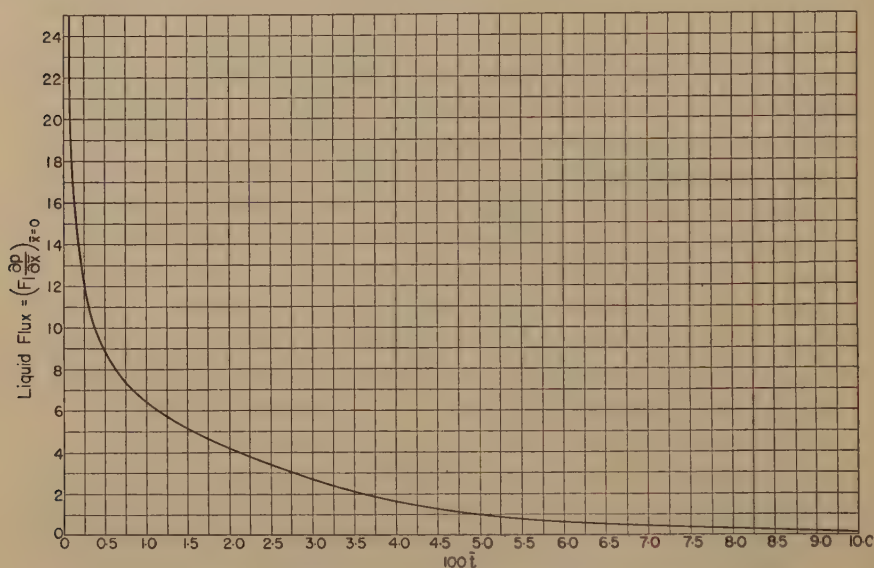


FIG. 13.—PRODUCTION DECLINE FROM THE SYSTEM.

to 99.5 per cent, while the production rate has declined to 0.0048 bbl. per day per sq. ft. of sand. After 194 days the pressure at the most distant point has fallen to 8.9 atmospheres, the outflow saturation to 72 per cent, the closed terminal saturation to 92 per cent, and the production rate to 0.0036 bbl. per day per sq. ft. of sand.

Thus far, of course, these results are not particularly striking. They indicate that the liquid recovery is definitely greater near the outflow face and decreases with considerable rapidity as one goes farther and farther into the sand. However, it cannot immediately be concluded that this actually happens in depleted fields. For the pressure at the distant terminal of 300 ft. after the 194 days of production will be 8.9 atmospheres and the average pressure over the whole sand body will be 60 per cent of its original value of 10 atmospheres. Hence this stage can obviously not be considered as representing a really depleted field from the

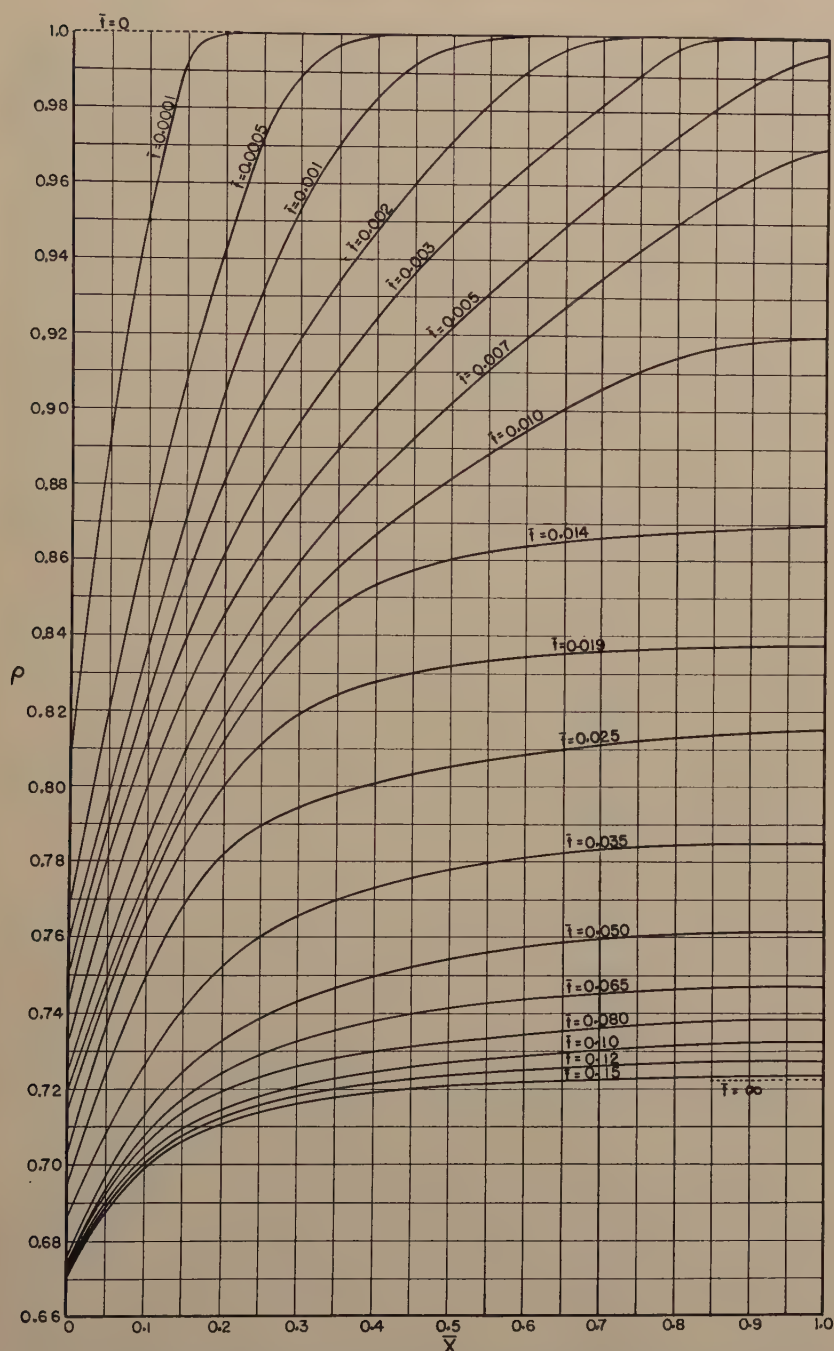


FIG. 14.—HISTORY OF DECLINE IN LIQUID CONTENT OF LINEAR CHANNEL WITH ONE TERMINAL CLOSED AND THE OTHER OPENED TO PRODUCTION.

1 — p = fractional depletion, $\bar{x}$ and $\bar{t}$ are dimensionless length and time defined by equation 12.

physical point of view, although, of course, the production rate available at that stage may well be approaching the limit of economic value. Moreover, the total recovery at this stage will be only approximately 60 per cent of that which would ultimately be withdrawn from the sand if one were to wait until the pressures had everywhere fallen to zero. Thus, for example, after three years of production from such a sand the pressure at the distant boundary will have dropped to 2.5 atmospheres, the saturation at the outflow face will have fallen to 67.5 per cent and that at the distant boundary will now have dropped to only 75.4 per cent, with the production rate declining to 0.0004 bbl. per day per sq. ft. of sand. And in the limit of absolute physical depletion, when the pressure has everywhere become atmospheric, the liquid saturation at the distant terminal will have dropped to 72.2 per cent, which is only 5 per cent in excess of that at the outflow face. The cumulative recovery at this stage will be approximately 28 per cent of the total initial liquid content.

That this approximate uniformity of the recovery over the whole length of the flow system is not simply an accidental result of the calcu-

TABLE 2.—*Recovery of Fluid from Unconsolidated Sand*

Distance from Outflow End, Ft.	Final Saturation, Per Cent	Average Saturation, Per Cent	Deviation from Average Satura- tion, Per Cent	Volume Produced, c.c.
1	73.5	71.7	+1.8	760
2	73.7		+2.0	
3	72.7		+1.0	
4	69.4		-2.3	
5	72.8		+0.9	
6	71.7		0.0	
7	69.8		-0.9	
8	70.3		-1.4	
1	71.2	72.3	-1.1	730
2	73.4		+1.1	
3	73.8		+1.5	
4	71.0		-1.3	
5	74.2		-1.9	
6	72.3		0.0	
7	71.5		-0.8	
8	71.3		-1.0	
1	71.6	71.8	-0.2	710
2	73.2		+1.4	
3	72.5		+0.7	
4	70.3		-1.5	
5	73.2		+1.4	
6	72.4		+0.6	
7	70.6		-1.2	
8	70.6		-1.2	

lations is shown by the data obtained on the ultimate saturation distributions in the flow tube in several of the experiments performed to test the relation between the ultimate recovery and equilibrium saturation, already presented in Table 1. The actual saturation distributions are reproduced in Table 2. Within the limits of the experimental errors, the direct experiments indicate an effectively uniform recovery everywhere along the flow channel. The theoretical predictions therefore must correspond to upper limits of the total variation in recovery that is to be expected for moderate saturation pressures.

Thus we see that as far as the *physical* depletion of the sand reservoir is concerned, the distant parts of the sand will ultimately yield almost as much of its liquid content, as will that in the vicinity of the well, and that only in the immediate neighborhood of the well will the recovery be appreciably greater than at distant points. In other words, the above theory gives no evidence for the existence of a "radius of drainage" that delimits and separates the part of the flow system in which there will be a large depletion as compared to that from which the recovery may be negligible. The immediate implication of this result, of course, is that the depletion or ultimate recovery will be essentially independent of the well spacing unless the latter be made so small as to become prohibitively expensive. It is true that the time that would be required to obtain the physical ultimate recovery referred to here will increase with the effective length of the flow system, that is, the well spacing, and indeed it will be directly proportional to the square of the spacing. However, the extent to which the saturation will ultimately fall will be for practical purposes quite independent of the dimensions of the system.

It is to be noted that in deriving these results it has been explicitly assumed that the sand is homogeneous throughout. When the latter is lenticular, it is clear that the spacing must be made sufficiently small to insure a high probability that each individual lens will be penetrated by at least one well. Beyond this restriction, however, the whole question of well spacing appears to reduce largely to one of economics in which must be balanced the value of a quick recovery of oil against the cost of additional wells and the associated additional investment, with the understanding that when the pressure within the sand has been reduced to any definite value the total recovery by that time will be essentially the same regardless of the number of wells involved. Moreover the same conclusion should apply in a physical sense when the sands are "tight," except in so far as the associated retardation in the depletion of the pressure at distant points may accentuate the economic problem of decreased rates of recovery and an increase in the period required for the return of the investment.

Although we have seen above that the equilibrium saturation of the sand corresponding to the equilibrium permeability determines a mini-

imum liquid recovery from the sand as long as the gas content is not too small, there may be derived analytically a continuous representation of the ultimate recovery as a function of the saturation pressure of the gas. In Fig. 15 is shown a particular form of this representation, in which is plotted the ratio of the initial pressure divided by the pressure when the saturation has fallen to p_e , as a function of p_e , this latter referring to the closed boundary of a heterogeneous fluid system. In so far as we have

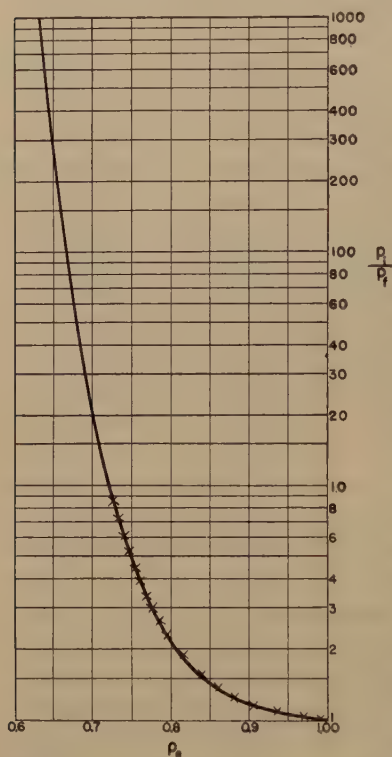


FIG. 15.—RELATION OF INITIAL SATURATION PRESSURE TO ULTIMATE RECOVERY.

seen that the liquid saturation p_e at such distant boundaries at the time of complete physical depletion is approximately the same as that over the sand as a whole, its value should be a good approximation to the liquid remaining in the sand after the ultimate recovery has been withdrawn from it. The theory then shows that for a given sand and gas-liquid mixture the ultimate recovery is largely determined by the initial saturation pressure, the variation being given by Fig. 15. The manner of production will affect mainly the part of the sand that is near the well, and to this extent the ultimate recovery will depend upon whether or not the sand is allowed to produce by wide open flow or by gradual pressure release. At distant points, however, the theory indicates that the initial gas-saturation pressure will be the predominating factor, although the actual variation of the recovery with the original gas-saturation pressure will be very small, as follows from the very rapid rise of the curve of Fig. 15. Whereas the recovery will be 28 per cent if the liquid is saturated to a pressure of 10 atmospheres, a further increase of recovery to 38 per cent would require an original saturation pressure of more than 1000 atmospheres. Conversely, the application of a vacuum, which would increase the ultimate value of the ratio of the initial pressure to the final reservoir pressure attainable for the sand, will again increase the ultimate recovery but very slightly, even if one should neglect the associated increases in liquid viscosity. Thus, for the case where the original saturation pressure is 10 atmospheres, the application of a vacuum so as to reduce the final average pressure over the sand to $\frac{1}{2}$ atmosphere would

seen that the liquid saturation p_e at such distant boundaries at the time of complete physical depletion is approximately the same as that over the sand as a whole, its value should be a good approximation to the liquid remaining in the sand after the ultimate recovery has been withdrawn from it. The theory then shows that for a given sand and gas-liquid mixture the ultimate recovery is largely determined by the initial saturation pressure, the variation being given by Fig. 15. The manner of production will affect mainly the part of the sand that is near the well, and to this extent the ultimate recovery will depend upon whether or not the sand is allowed to produce by wide open flow or by gradual pressure release. At distant points, however, the theory indicates that the initial gas-saturation pressure will be the predominating factor, although the actual variation of the recovery with the original gas-saturation pressure will be very small, as follows from the very rapid rise of the

increase the ultimate recovery by only 2 per cent above that obtainable without the application of a vacuum.

Returning again to the general features of the decline history of the sand column, the variation of the gas-liquid ratio is shown in Fig. 16. It is to be noted that the gas-liquid ratio increases continuously to an asymptotic value with the age of the system. Here again we have a general conclusion with regard to a question that has been difficult to settle simply on the basis of field observations, although from the point of view of the present study the continuous rise in the gas-liquid ratio is really an obvious necessity. For since the gas-liquid ratio increases uniformly with the decreasing liquid saturation the continuous decline in the latter at the face of a well necessarily means a steady growth in the gas-liquid

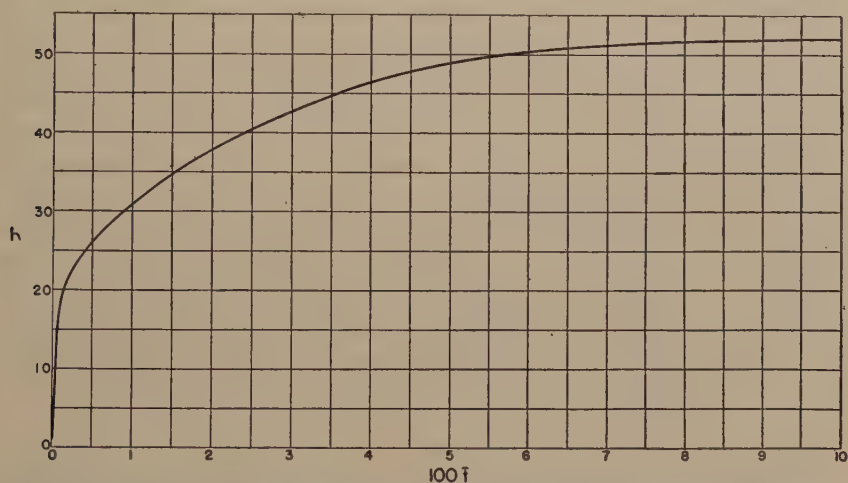


FIG. 16.—HISTORY OF GAS-LIQUID RATIO (GAS VOLUME AT ATMOSPHERIC PRESSURE—LIQUID VOLUME) IN PRODUCTION FROM A LINEAR CHANNEL CLOSED AT ONE TERMINAL. Normal gas-liquid ratio of solution = 10.0.

ratio. Of course, this conclusion assumes that the pressure at the sand face is initially reduced to its ultimate low value, or that its changes during the production history are always of a decreasing nature. Under such conditions the continuous rise in the gas-liquid ratio will be inevitable.

Although other features of the performance of oil-producing reservoirs might be given a qualitative discussion on the basis of the experiments and theory developed here, those already considered will suffice to show the practical applicability of this work. On the other hand, it is to be emphasized that while the conclusions with regard to well spacing, ultimate recovery, etc. have been stated in a rather dogmatic manner as being applicable to actual field conditions, this has been done only in order to avoid repeated qualifications as to the limitations of the theory and experiments. For, in fact, we wish it to be explicitly understood that at the present time these conclusions will have validity only when

applied to unconsolidated sands. No pretense whatever is made that they may be extrapolated without modification to the production of gas and oil from consolidated sandstones. While it is true that we find no reason to anticipate *radical* changes in the behavior of gas-liquid mixtures when the experiments will be extended to consolidated sands, it may well turn out that even minor modifications in the fundamental characteristics may materially alter the practical consequences. This work is therefore not to be construed, for example, as advocating wide well spacing and the use of arbitrary production methods, although such conclusions do seem to follow from the purely physical properties of unconsolidated sands carrying gas-liquid mixtures. And even if these features should carry over into the domain of consolidated sands, it is, of course, to be recognized that the economic aspects of oil production merit at least equal if not greater consideration than the strictly theoretical and physical phases of it. Moreover, the structural configuration of the producing sand—a very important factor in the development of actual oil reservoirs—has been explicitly excluded from our consideration of the questions of well spacing and ultimate recovery. This limitation must also be recognized in the application of the results developed here to specific programs of oil production. We do hope, however, that we have shown in this paper that gas-liquid mixture systems can be studied by relatively simple physical methods, and that such studies lead to results that are not only subject to physical interpretation but can also be correlated with the practical questions of oil production.

ACKNOWLEDGMENTS

The authors wish to thank Mr. D. W. Reed and Dr. W. N. Arnquist for assistance during the course of the work reported here, and Dr. Paul D. Foote, Executive Vice-president of the Gulf Research & Development Co. for permission to publish this paper.

DISCUSSION

(*M. Albertson presiding*)

The general view was expressed that this highly technical paper, resulting from three or more years of research, should be studied thoughtfully because of the significance of the experimental data as they pertain to the pressure distribution around producing wells, the inferences regarding the effectiveness of wide spacing of wells in unconsolidated sands under the conditions of the tests, and the value of energizing gas caps in stimulative-recovery operations. Also, the general expression was that the authors have presented a basis for a better understanding of practical considerations in the well-spacing problem.

Oil-well Behavior Based upon Subsurface Pressures and Production Data

By H. C. MILLER,* MEMBER A.I.M.E., E. S. BURNETT† AND R. V. HIGGINS‡

(New York Meeting, February, 1937)

INFORMATION obtained from subsurface pressure and temperature measurements in oil wells now is recognized as invaluable to geologists, engineers, and operators of oil properties. Available only during the past few years, data resulting from subsurface-pressure surveys in oil wells already have found widespread application in the estimation of reserves and in the planning of comprehensive oil-field development programs. Subsurface pressure and temperature data, together with measurements of fluid volumes produced by individual wells and specific gravities of the fluids, also are included in the fundamental information essential in studying the movement of oil, gas and water through reservoir sands to wells. Heretofore, laboratory findings were relied upon almost entirely for information pertaining to the mechanics of flow of fluids through porous media, because there was no way to check laboratory results with actual performance in underground formations until subsurface pressure and temperature instruments were developed. Laboratory and field experiments now lend themselves to closer correlation—a fact that will accelerate the interpretation of many phenomena that occur when oil and gas flow through reservoir rocks, thousands of feet below the surface of the earth.

This paper summarizes the results obtained thus far in a Bureau of Mines study of certain data pertaining to subsurface pressures and production of wells producing oil and gas (and water). For wells that have been studied, flowing naturally under volumetric or hydraulic control, a simple relation has been found between the mass rate of fluid (oil, gas and water) production and the corresponding drop in pressure in the reservoir sand. The equated relation embodies a productivity factor or “index” expressed in terms of mass rate of fluid production per pound drop in pressure through the sands. The equation as developed is an expression of the ability of a well to produce, which permits comparison on a uniform basis of the productivities of different wells. The study shows also that over the range of observed data a productivity factor

Published by permission of the Director, U. S. Bureau of Mines. Manuscript received at the office of the Institute Jan. 20, 1937.

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based on mass rate of production is a constant for a given well at different rates of flow. In other words, the mass rate of production is a straight-line function of the drop in pressure through the reservoir sand.

Substitution in the equation of actual pressure determinations and corresponding production data obtained while a well is flowing permits computing the average static pressure opposite the producing sand in a well. Thus, if two (but preferably three or more) sets of pressure-flow data are obtained from a well, the average pressure that would exist opposite the productive sand or zone, if the well were shut in, can be determined.

SOURCE OF DATA

In May and June 1935, subsurface pressure and temperature traverses were run by representatives of the Oil Umpire for the Central Committee of California Oil Producers in a large number of wells in the Kettleman North Dome oil field, California. Through the courtesy of R. E. Allen, then Assistant Oil Umpire, and the officials of several of the companies on whose wells the tests were made, reservoir and production data resulting from this pressure-temperature survey were made available to the Bureau of Mines for use in its study of flow of oil, gas and water through reservoir sands. Later, certain data acquired during subsequent surveys on the Kettleman North Dome Association holdings were made available to the writers. Data of a type similar to those on Kettleman Hills wells were collected also on wells in the Dominguez, Playa del Rey, and Padre Canyon fields, California; Hobbs field, New Mexico; Rodessa field, Louisiana; and the East Texas field, Texas.

In the course of the study reported in this paper, data were collected from more than 150 wells. The observations on many of the wells, however, were incomplete or unsuitable for the purpose of investigating the flow of fluids through reservoir sands because some essential information was lacking or obviously in error. For example, the data collected from wells reported to have been surging or heading badly during flow tests were eliminated from consideration because it was found that pressure and volume observations were affected uncertainly by unsteady flow. Test data from wells tubed below the top of the producing sands also were set aside temporarily to eliminate from consideration pressure determinations that might be inaccurate because of restriction of the flow channel by the pressure instrument. This report, therefore, is based on the study of pressures, production, and related data from 45 wells.

AN EQUATION FOR FLOW OF FLUIDS THROUGH RESERVOIR SANDS TO WELLS

The collected data concerning depths and pressures opposite the producing sands were plotted on depth-pressure charts, as shown in

Fig. 1. The best curve was drawn through each set of plotted points representing the pressure traverse for one condition of flow (zero flow for the traverse made while the well was shut in). The average pressures between the top and bottom of the producing sands were determined from the depth-pressure curves by means of a planimeter.

The drops in pressure between the average formation (static) pressure and the different average flowing pressures then were determined, and the differential pressures were plotted on logarithmic paper against the corresponding mass rates of fluid (oil, gas and water) production per 24 hr. In a large number of wells a definite relation between the pressure drop in the producing sands and the combined or total mass rate of (fluid) production was found to exist. This relation, as represented graphically on logarithmic paper, is a straight line having a 1 to 1 slope.

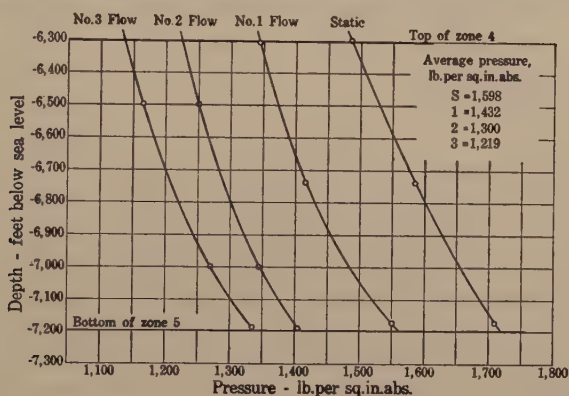


FIG. 1.—DEPTH-PRESSURE CURVES FOR STATIC CONDITIONS AND THREE RATES OF FLOW IN A WELL IN THE KETTLEMAN HILLS FIELD, CALIFORNIA.

Fig. 2 shows the graphs on logarithmic paper for 17 wells where the mass rate of production per 24 hr. is plotted against the drop in pressure through the sands for different rates of flow. This relation was found to hold for many other flowing wells in several oil-producing districts of the United States, but for clarity their graphs are not shown on this chart. The relation between the mass rate of fluid production and the pressure drop in the sand, shown graphically in Fig. 2, can be expressed mathematically by the linear equation:

$$\log M = \log C + \log (P_f - P_s)$$

or in arithmetic coordinates by:

$$M = C(P_f - P_s)$$

where M = mass rate of fluid production, lb. per 24 hr.

Also:

$$M = Q_o w_o + Q_g w_g + Q_w w_w$$

where Q_o , Q_g and Q_w are the respective volume rates of production of oil, gas and water in cubic feet per 24 hr. at 60° F. and atmospheric pressure, and w_o , w_g and w_w are the corresponding densities in pounds per cubic foot.

P_f = average "shut in" formation pressure in the well opposite the productive sands, lb. per sq. in. abs.

P_s = average back pressure (flowing pressure) opposite productive sands in the well, lb. per sq. in. abs.

$P_f - P_s$ = pressure drop producing flow through the sands, lb. per sq. in.

C = coefficient, numerically equal to mass rate of flow of fluids per pound pressure drop through the sand; in other words, a productivity factor or "index." C has the same numerical value as M when $P_f - P_s = 1$; or since the slope of the lines on Fig. 2 is 1 to 1, C is $1/100$ of M , read at $P_f - P_s = 100$.

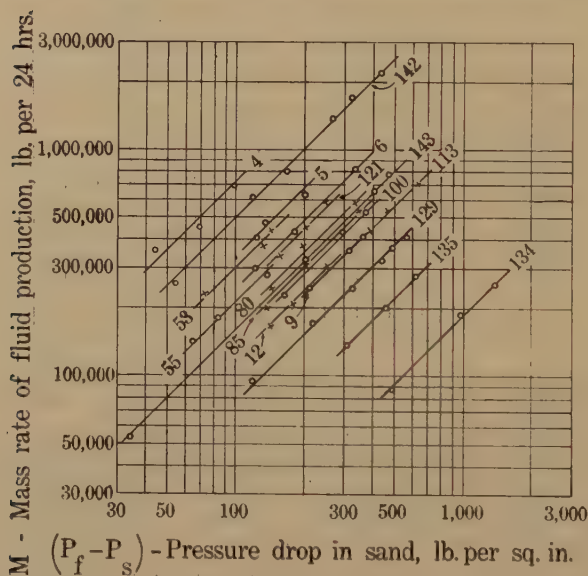


FIG. 2.—RESULTS OF TESTS ON 17 OIL WELLS, SHOWING STRAIGHT-LINE RELATION BETWEEN M AND $(P_f - P_s)$.

129, well in Dominguez field, California; 134 and 135, wells in Playa del Rey field, California; 142, well in Rodessa field, Louisiana; 143, well in East Texas field, Texas; all others, wells in Kettleman Hills field, California.

Ordinary arithmetic plotting of the values plotted in Fig. 2 would yield straight lines through the origin ($M = 0$, $P_f - P_s = 0$). The slopes of these straight lines (C) are the mass rates of production per pound pressure drop through the sand, or the productivity "indices."

It should be emphasized that the straight-line relation between the drop in pressure and the mass rate of flow of heterogeneous fluids through reservoir sands presented in this paper is merely an empirical statement of

the facts found on plotting the data pertaining to the wells in several fields that have been studied. The relation may not be supported completely on a rational basis; it has rational support only for an incompressible fluid and viscous flow—conditions that probably were approached in the flow of undersaturated oil through reservoir sands in the East Texas field studied by Reistle and Hayes¹. However, certain factors in the flow of compressible fluids through reservoir sands may have compensating influences that make the relation hold in a large number of wells. Perhaps, after additional data have been collected and analyzed more rigorously than has been possible in the preparation of this paper, some modification of the equation may be necessary. However, until instruments are built that will record subsurface pressures more accurately than is possible with those now in general use, it is believed that the relation as expressed can be considered a close approximation for flow of mixtures of oil and gas through many reservoir sands and that application of the empirically developed equation will be helpful in studying performance of wells and reservoirs.

C , in the equation $M = C(P_f - P_s)$, numerically is equal to the mass rate of flow of all fluids entering the well per pound drop in pressure through the reservoir sand. As such, C is a measure of the ability of a sand to produce and therefore a productivity factor or "index." It is well known that oil sands generally are not uniformly permeable from top to bottom or even laterally over the area of the reservoir. For that reason, C cannot be considered an absolute measure of permeability. Many producing zones, especially in California, comprise a series of oil sands, sandy shales that may bear oil, and nonproductive shales. Furthermore, the shale strata interbedded between layers of productive sand range in thickness from a fraction of an inch to many feet and may or may not be continuous throughout the extent of the reservoir. Obviously, in a system as complex as an oil reservoir, the characteristics of each sand layer or the effect on average permeability of shale lenses in the sands cannot be evaluated accurately.

As many oil sands consist of alternate layers of productive sand and nonproductive shales, it seems reasonable to conclude that any measure of permeability that would be helpful in comparing the productivity of wells drilled in productive zones of that type should consider only those strata in the sand section that are oil and gas-bearing. To be able to make such comparisons, however, would require accurate knowledge of the cumulative thickness of the productive strata exposed to the well. Unfortunately, the thickness of shale breaks in oil zones is not always measured and recorded on the drillers' log sheets, and electrical logging of

¹ C. E. Reistle, Jr. and E. P. Hayes: A Study of Subsurface Pressures and Temperatures in Flowing Wells in the East Texas Field and the Application of these Data to Reservoir and Vertical-flow Problems. U. S. Bur. Mines *R.I.* 3211 (1933).

oil zones has not yet become a part of the drilling procedure in all wells. Furthermore, in California, oil strings generally are perforated from the top to the bottom of the productive zones; blank pipe is set between the zones, and no attempt usually is made to "blank off" nonproductive strata within oil zones. Therefore the number of feet of perforated pipe in a well is not necessarily a measure of the net thickness of the productive sand exposed to the well. The only information available to the writers on wells included in their study is the number of feet of perforated pipe in the wells—in other words, the combined thickness of the several oil zones exposed in the wells. Accordingly, for comparative purposes, all calculations of the productivity of wells were made on the basis of their "specific productivity" C' —pounds of fluids produced by the wells per 24 hr. per foot of oil zone exposed in the well per pound difference between the average formation (static or shut-in) and flowing pressures. Such a comparison is based on the assumption that the entire thickness of each producing zone is uniformly productive, which, of course, is not true. However, until more detailed information on net thicknesses of producing zones is available, comparisons between wells on the basis of their specific productivities are believed to be more significant than those based on average productivities.

CONSTANCY OF WELL PRODUCTIVITY WITH TIME

Although insufficient field data have been collected to permit making any conclusive statements as to the constancy of, or variation in, the productivity of wells with time and with changes in production practices, a number of interesting deductions can be made. The following statements and those appearing in the next section on the productivity of offset wells, therefore, are observations rather than definite conclusions.

Table 1 shows values of C (productivity factor) and C' (specific productivity factor) at different periods in the life of nine wells in the Kettleman Hills field. The small differences in the values for C and for C' in wells Nos. 9, 12, 59, 85 and 96, and the fact that in most of the wells the productivity did not increase (or decrease) uniformly with time but changed irregularly, suggest that in some wells the productivity factor is relatively constant over periods as long as 8 or 9 months.

Changes in well productivity may result from a number of different causes. Decreasing productivity signifies that the mass flowing through the sands to the well per pound drop in pressure is decreasing with time and indicates possible clogging of the sand face by sand, silt, waxy substances, or other materials, or drainage interference by other wells. On the other hand, if the productivity factor of a well increases with time it may be evidence that the well is "cleaning itself out" and that the resistance to flow at the sand face is decreasing. If the well produces sand along with the oil and gas, the increase in productivity per pound drop in

pressure through the sand may indicate that channels have been created in the reservoir or that the effective radius of the well bore is increasing.

TABLE 1.—*Changes in Well Productivity with Time*
Nine Wells in the Kettleman Hills, Calif., Field

Well Example No.	Months during Which Tests Were Made	Productivity Factor C, Lb. Fluid per 24 Hr. per Lb. Pressure Drop in Sand	Perforations Exposed to Sands in Well, Ft.	Specific Productivity Factor C', Lb. Fluid per 24 Hr. per Lb. Pressure Drop in Sand per Foot of Sand
9	May, 1935.....	1130	441	2.6
	Dec., 1935.....	1000	441	2.3
	Feb., 1936.....	1065	441	2.4
12	May, 1935.....	1185	450	2.6
	Dec., 1935.....	1100	450	2.4
	Feb., 1936.....	1335	450	3.0
13	May, 1935.....	5810	874	6.6
	Jan., 1936.....	3110	874	3.6
	Feb., 1936.....	2435	874	2.8
	Mar., 1936.....	3470	874	4.0
31	May, 1935.....	4530	1089	4.2
	Jan., 1936.....	5080	1089	4.7
	Feb., 1936.....	6430	1089	5.9
39	May, 1935.....	2970	900	3.3
	Feb., 1936.....	1685	900	1.9
	Apr., 1936.....	2340	900	2.6
58	June, 1935.....	2865	895	3.2
	Feb., 1936.....	4240	895	4.7
	Apr., 1936.....	3730	895	4.2
59	May, 1935.....	2340	869	2.7
	Jan., 1936.....	2060	869	2.4
85	May, 1935.....	1625	880	1.8
	Jan. 1936.....	1625	880	1.8
96	May, 1935.....	1050	988	1.1
	Jan., 1936.....	1295	988	1.3
	Mar., 1936.....	1360	988	1.4

The relatively small increase (or decrease) in the productivity factor during an 8-month period indicates that the change in the ability of a sand to produce fluids per pound pressure drop must be gradual and of small magnitude during periods of a month or two. Therefore, if the productivity factor of a well remains constant, or nearly so, for one or a few

months, after the factor for a well is once established it may be used conveniently during the period in which it remains relatively constant to regulate production practices in accordance with desired rates of production or pressure drop through the sand.

COMPARISON OF PRODUCTIVITY OF OFFSET WELLS PRODUCING FROM SAME ZONES

The data studied in connection with this report contained field tests on a number of sets of adjoining wells producing from the same zones in the Kettleman Hills field. Wells 9 and 12 (Table 1) were approximately 1800 ft. apart; their specific productivity factors in May 1935 were identical, varied by 0.1 (4 per cent) in December 1935, and differed by 0.6 (25 per cent) in February 1936. Well 58 (Table 1) was 1300 ft. from well 59, yet in the summer of 1935 their specific productivity factors differed by 0.5, or 18.5 per cent. Two other offset wells, 1585 ft. apart in the northern end of the North Dome of Kettleman Hills and producing from the same zones, had specific productivity factors in May 1935, of 2.6 and 2.4—a difference of 8 per cent; another set of wells spaced 1425 ft. apart had specific productivities of 4.6 and 4.2—a difference of 9 per cent—indicating a certain degree of uniformity of permeability of the sands about the two pairs of wells. That the specific productivities of all pairs of wells are not necessarily in close agreement is shown by the fact that in two wells 2000 ft. apart the specific productivity factor for one was 11.8 and for the other 8.5—a difference of 40 per cent. These high specific productivity factors indicate relatively open or permeable sands, and it is to be expected that a considerable difference in productivity of adjacent wells will exist in such sands.

Although data for some pairs of wells in the Kettleman Hills field show relatively wide variations in their indicated specific productivity factors, similar data pertaining to another part of the field indicate that the permeability of the productive sands, extending over quite wide limits, is more uniform than engineers heretofore have had reason to expect. For example in an area $\frac{1}{4}$ mile wide and $1\frac{1}{4}$ miles long, six wells had specific productivity factors of 3.2, 3.8, 3.2, 4.2, 4.6, and 4.2, respectively.

DETERMINING AVERAGE FORMATION PRESSURES FROM FLOW DATA

To determine the average formation (shut-in) pressure in a well, engineers have found it necessary to shut in the well for 24 hr. or longer to allow pressures in the well opposite the sand face and in the formation about the well to equalize before lowering a pressure instrument and making a pressure traverse. At best one or more day's production is lost on the flowing schedule while waiting for pressures to equalize, and

frequently wells fail to "come back" and produce oil at their former rate after having been shut in for even so short a period as 24 hr. An example may be cited also where an operator greatly desired to know the pressure opposite the productive sand in a well but feared to close the surface valves to permit equalization of well and reservoir pressures because of the high pressure that would have developed in the well if it were closed in. For these and perhaps other reasons, many operators are anxious to find some method whereby static pressures in wells can be determined without closing the wells.

If the pressure drop in the sand is proportional to the mass rate of production, in accordance with the relation $M = C(P_f - P_s)$, conforming to the indicated graphical study previously discussed, it is possible to estimate P_f , the most probable average formation (shut-in) pressure—corresponding to zero production—and $\frac{M}{P_f - P_s}$ or C , the most probable average mass rate of production of a well per pound drop in pressure through the sand, from flowing data alone. Furthermore, if subsequent studies show that the relation between pressure drop and mass rate of fluid production holds for flow conditions beyond the range of experimental data studied so far, it will be possible to estimate the maximum fluid production rate (well potential) at any limiting pressure at the sand face within the capacity of production equipment without making open-flow tests.

When no measurements of the static or shut-in pressure opposite the productive sands have been made and two or more sets of pressure and production data have been obtained from a well, a close estimate of the average static pressure across the sand face exposed in the well can be made by plotting on rectangular coordinate paper average pressures at the sand face while the well is flowing against the corresponding mass rates of flow. The best straight line through the plotted points extended to the abscissa representing zero flow gives the average static pressure. Extending the best straight line in the opposite direction to any limiting sand-face pressure shows the maximum fluid production rates of the well at that pressure.

Average pressures at the sand face are plotted against the mass rate of flow for 15 wells in Fig. 3. Best straight lines are drawn through the plotted points and extended to the left to intersect the abscissa representing zero flow where the average static pressure across the sand face in the well may be read. For three of the wells, the best lines through the plotted points have been extended (by dashed lines) to the ordinate representing a limiting pressure of 100 lb. per sq. in. abs. This was done to estimate the potential production rate of the wells, in pounds of fluid per 24 hr., at that limiting average back pressure against the producing sands.

Static-pressure surveys had been made in each of the 15 wells represented in Fig. 3. However, the static-pressure reading was disregarded when the position of the best straight line through the points representing

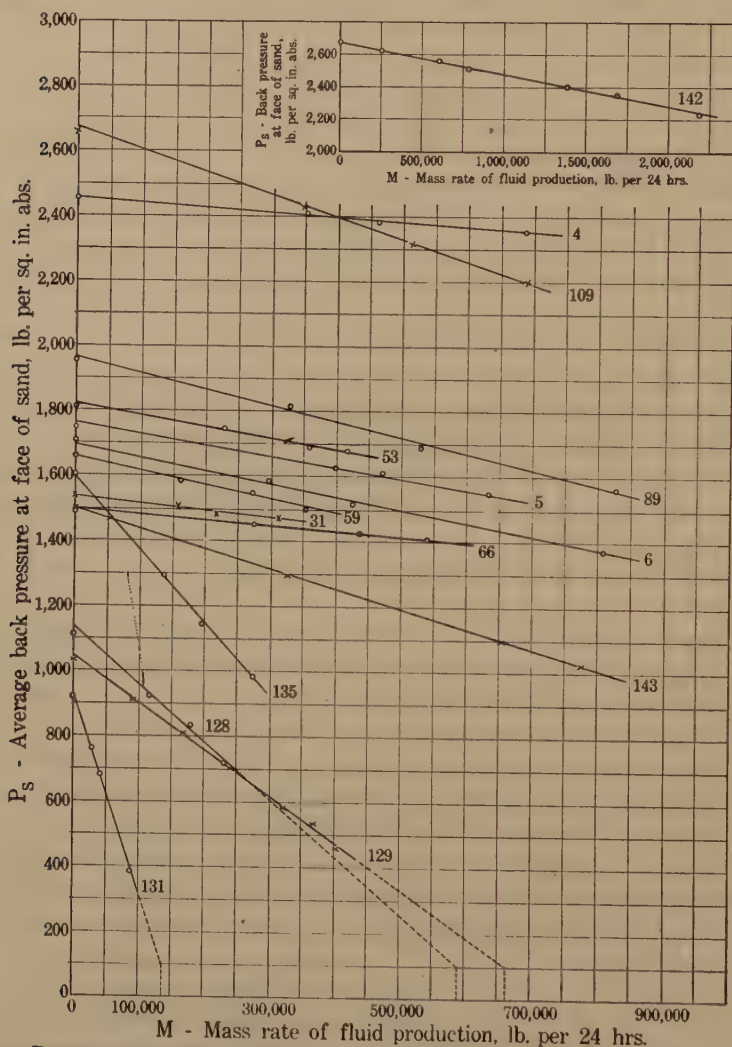


FIG. 3.—RESULTS OF TESTS ON 15 OIL WELLS SHOWING STRAIGHT-LINE RELATION BETWEEN P_s AND M .

128, 129 and 131, wells in Dominguez field, California; 135, well in Playa del Rey field, California; 142, wells in Rodessa field, Louisiana; 143, well in East Texas field, Texas; all others, wells in Kettleman Hills field, California.

flowing data was determined. The difference in average static pressure between that determined from actual measurements and that determined by the best straight line through the points representing flowing data may be noted by the disparity between the plotted static-pressure reading

and the point of intersection of the best straight line with the zero ordinate. For some of the wells, the difference is so small that it cannot be shown on the scale used in drawing Fig. 3.

The slopes of the lines referred to the P_s axis are, in numerical values, directly proportional to the productivity indices of the wells. The fact that the slopes of the lines representing different wells are not the same indicates that the average productivities of the wells differ.

TABLE 2.—*Gas-oil Ratios, and Measured and Computed Values of the Average Formation (Static) Pressure in 19 Oil Wells in Several Different Fields*

Well Example No.	Variation in Gas-oil Ratios, Cu. Ft. per Bbl.	Pressures, Lb. per Sq. In. Abs.		Differences Calculated Minus Measured	
		Measured	Calculated	Lb. per Sq. In.	Per Cent
Kettleman Hills, California					
4	561- 883	2,450	2,456	+ 6	+0.2
5	938- 1,010	1,747	1,767	+17	+1.0
6	1,348- 1,414	1,705	1,695	-10	-0.6
9	522- 697	1,815	1,813	- 2	-0.1
17	640- 685	1,714	1,718	+ 4	+0.2
31	751- 852	1,537	1,532	- 5	-0.3
53	807- 1,185	1,818	1,822	+ 4	+0.2
59	636- 813	1,655	1,653	- 2	-0.1
66	1,025- 1,135	1,479	1,500	+21	+1.4
76	656- 768	1,548	1,562	+14	+0.9
89	2,820- 3,010	1,960	1,964	+ 4	+0.2
100	2,348- 3,820	1,598	1,600	+ 2	+0.1
109	13,490-15,790	2,657	2,678	+21	+0.8
Dominguez, California					
128	1,138- 1,312	1,111	1,133	+22	+2.0
129	940- 1,350	1,030	1,048	+18	+1.7
Playa del Rey, California					
134	27,600-41,700	1,618	1,596	-22	-1.4
135	4,300- 4,765	1,604	1,598	- 6	-0.4
Rodessa, Louisiana					
142	3,024- 5,973	2,670	2,664	- 6	-0.2
East Texas, Texas.....					
143	300	1,500	1,496	- 4	-0.3

Table 2 shows the average formation (static) pressure actually measured in 19 wells in several different fields and the average formation pressure calculated by the method of least squares² from data taken

² For an excellent discussion of the method of least squares see J. W. Mellor: Higher Mathematics for Students of Chemistry and Physics. New York, 1931. Longmans, Green & Co.

while the wells were flowing. The table also shows the difference, in pounds per square inch, between the computed and measured formation pressures and these differences expressed as a percentage of the measured pressure.

SUMMARY

The study of the observed data on subsurface pressures opposite the productive sands and related production data on wells in the Kettleman Hills, Dominguez, Playa del Rey, and Padre Canyon fields, California; Hobbs field, New Mexico; Rodessa field, Louisiana; and East Texas field, Texas, shows a simple definite relation between the mass rate of fluid (oil, gas and water) production and the drop in pressure causing flow through the sands. When the mass rates of production for different rates of flow in a well are plotted on logarithmic paper against the difference between the average formation (static or shut-in) and flowing pressures opposite the producing sands, the relationship between them is represented by a straight line, which may be expressed mathematically by the equation:

$$M = C(P_f - P_s)$$

where M = mass rate of fluid (oil, gas and water) production, lb. per 24 hr.

C = coefficient, numerically equal to mass rate of flow of fluids per pound pressure drop through the sands.

P_f = average "shut-in" formation pressure opposite the producing sands, lb. per sq. in. abs.

P_s = average back pressure (flowing pressure) in the well opposite the producing sands, lb. per sq. in. abs.

Substitution of observed well data for the terms M , P_f and P_s in the equation permits calculating values for C , the productivity factor or index for the well, or both P_f and C may be determined by substituting numerical values of M and P_s of two or more rates of flow. The study indicates, for the range of production observed in the tests forming the basis of this report, that C is a constant in a given well for all rates of flow. In a number of wells, C did not change (within the limits of accuracy of the reported data) during an 8-month period while the wells were producing regularly or alternately flowed and shut in for periods of time. In a number of other wells C did not remain constant during an 8-month period. In those wells where C increased, the probable indication is that the wells were "cleaning themselves out" or that a readjustment of the sand particles immediately about the wells was reducing the resistance to flow of fluids into the well bores. When C decreased with time, or, in other words, when a smaller mass of fluids entered the wells per pound drop in pressure through the sand, a condition of clogging at the sand face, or plugging of the perforation in the oil string, is suggested.

A study of several pairs of wells and one group of six wells producing from the same sands in the Kettleman Hills field showed that the "specific productivity" of reservoir sands, as indicated by the pounds of fluids flowing to the wells through one foot of sand thickness per 24 hr. per pound drop in pressure, may be fairly uniform over extended areas. However, observations on other sets of flowing wells in the Kettleman Hills field showed that this condition does not always hold and that neighboring wells producing from the same sands may differ considerably in "specific productivity."

Application of relations that may be found between rates of fluid production and differential pressures in producing sands will aid in developing a better understanding of reservoir performance and the related problem of well spacing. Since the straight-line relation discussed in this paper is merely an empirical statement of the facts found on analyzing limited field data, and may not be supported completely on a rational basis, Bureau of Mines engineers invite contributions of oil-well production data and subsurface pressure and temperature traverses to be used in continuing their check and further analysis of what appears to be a useful relation.

ACKNOWLEDGMENTS

The study of subsurface pressure and temperature data is being made under the supervision of R. A. Cattell, Chief Engineer, Petroleum and Natural Gas Division, Bureau of Mines. The writers wish to thank R. E. Allen, former Assistant Oil Umpire, Central Committee of California Oil Producers and now with A. O. Smith Corporation; William Reinhardt, General Manager, Kettleman North Dome Association; A. C. Rubel, Union Oil Company of California; A. H. Bell, Continental Oil Company of California; and E. A. Wahlstrom, Stanolind Oil and Gas Co., for furnishing the well data upon which this study is based. Thanks are due also to the following engineers for their constructive criticism of the manuscript: H. N. Marsh and B. H. Robinson, General Petroleum Corporation of California; A. H. Bell, Continental Oil Company of California; H. C. Pyle, Union Oil Company of California, all having headquarters in Los Angeles, Calif.; R. C. Patterson, U. S. Geological Survey, Taft, Calif.; and the following members of the Bureau of Mines, R. A. Cattell, H. C. Fowler, C. W. Seibel, Gustav Wade, C. B. Carpenter and G. B. Shea.

DISCUSSION

(M. Albertson presiding)

E. L. RAWLINS,* Houston, Texas (written discussion).—Messrs. Miller, Burnett and Higgins have suggested a possible, very useful, relationship between mass rate of

* United Gas Public Service Co.

fluid production and drop in pressure causing flow through producing formations. It will be particularly interesting and important to study this relationship, or a modification of it, in connection with production of oil and gas from high gas-oil ratio wells; also, it is hoped that some considerable study can be made to segregate the oil and gas separately from the total mass rate of flow relationship.

This will mean a more thorough knowledge of variation in gas-oil ratio with rate of flow from different types of formations and under different pressure conditions. The use of a fundamental relationship between mass rate of flow and pressure drop across the sand should be useful in the study not only of the gas-oil ratio problem but also many other problems pertaining to mechanics of fluid flow through sand.

M. MUSKAT,* Pittsburgh, Pa., in commenting upon the relation between mass rate of fluid production and the corresponding drop in pressure in the reservoir sand, as developed by the authors, stated that while such a relation might be anticipated for wells having relatively small variations in gas-oil ratios (see Table 2), deviations would be expected when the gas-oil ratios would be varied over a wide range, and suggested that a valuable check might be obtained by studying similar data for wells having wide variations in gas-oil ratios.

Mr. Miller expressed the opinion that there may be some influences upon fluid flow in reservoir sand, not now thoroughly understood, that tend to compensate one another even in wells with widely varying gas-oil ratios.

R. A. CATTELL,† Washington, D. C., pointed out the relation of the work leading to the present paper and the studies of the behavior of natural-gas wells made by the Bureau of Mines wherein it was found that the rate of flow is proportional to the difference of the squares of the pressures raised to a power, and that the coefficient of proportionality is constant over time if well conditions do not change.

C. V. MILLIKAN,‡ Tulsa, Okla., suggested a practical application of the work in finding the cause of trouble in wells, by comparing the slopes of curves plotted from data taken at different times during the decline of the well.

B. E. LINDSLY,§ Washington, D. C., saw possibilities of allocating production on an equitable basis by means of the relationship.

S. PIRSON,|| State College, Pa. (written discussion).—As pointed out by Mr. R. A. Cattell, it is interesting to compare the present equation of mass withdrawal of oil

$$M_{oil} = C_1(P_f - P_s)^n$$

to the equation of volumetric withdrawal of gas from a well

$$Q_{gas} = C_2(P_f^2 - P_s^2)^n$$

previously established by E. L. Rawlins and H. A. Schellhardt, of the Bureau of Mines. In these equations M_{oil} is the mass of liquid, oil and water withdrawn in 24 hr., Q is the volume of gas withdrawn in 24 hr. and taken at atmospheric pressure and temperature, P_f is the shut-in formation pressure in pounds per square inch

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absolute, P_s the sand-face back pressure (during flowing condition) in pounds per square inch, n the slope of the straight lines representing the above equation on log-log paper and C_1 and C_2 are constants. A further advance at comparing these equations can be made by the following considerations.

First of all, the gas equation can be expressed in function of the mass by merely introducing the concept of gas density ϑ_0 at atmospheric pressure P_0 . The gas equation becomes the following:

$$M_{\text{gas}} = C_2 \vartheta_0 (Pf^2 - P_s^2)^n$$

which can also be written as follows:

$$M_{\text{gas}} = 2^n C_2 \vartheta_0 \left(\frac{Pf + P_s}{2} \right)^n (Pf - P_s)^n$$

where $Pf + P_s$ is the average formation pressure.

Or:

$$M_{\text{gas}} = C \vartheta_0 \left(\frac{Pf + P_s}{2} \right)^n (Pf - P_s)^n$$

In the curves published by Rawlins and Schellhardt, it is shown that the values of the slopes n are smaller than one and there is a possibility that the above expression can be written as a function of the percentage of deviation of the natural gas from Boyle's law. Thus we obtain:

$$M = C \vartheta_0 \frac{Pf + P_s}{2} \left(1 - \frac{N}{100} \right)^\alpha (Pf - P_s)^n$$

The subscript to M is purposely left out, as this equation represents as well the performance of an oil well, in which case $N = 0$ and very little change in the value of the density ϑ_0 takes place.

One can further make the consideration that the exponent n is a dimensionless quantity which is in all probability a function of at least the permeability of the formations and the mean radius of the surface affected by drainage, or, in other words, of the well spacing. Permeability has the dimensions of a surface thus the above equation becomes in its final form:

$$M = C \vartheta_0 \frac{Pf + P_s}{2} \left(1 - \frac{N}{100} \right)^\alpha (Pf - P_s)^\beta \frac{k}{R^2}$$

in which k is the permeability, R the well spacing and α and β are constants. M represents the mass withdrawal of all fluids: gas, oil and water.

It has not been possible to check the above equation for lack of data and it is here merely suggested as a new line of thought.

The Productivity Index

By M. L. HAIDER*

(Fort Worth Meeting, October, 1936)

MUCH has been said and written on the shortcomings of the open-flow and restricted potentials of oil wells to determine their relative ability to produce. The oil industry in general is agreed that the open-flow potential in particular is grossly inequitable, wasteful and expensive, but that potential is still used in many pools. This is partly because no thoroughly satisfactory substitute has been found and partly because operators are reluctant to adopt other methods that have been suggested; or, as Hamlet would say, we would rather "bear those ills we have than fly to others we know not of."

In a great many pools the use of tubing potentials has been substituted for open-flow potentials, but open-flow potentials through casing are still being used in many pools, particularly in Oklahoma, although the expense of such potentials has been pointed out many times. In one of the most recent pools in Oklahoma it is the practice to take open-flow potentials through the casing with the tubing out of the hole. The well is usually tubed after it is drilled in for the purpose of washing it in and cleaning the hole. After preliminary tests are run the tubing is pulled under pressure preparatory to taking the potential. After the potential is taken the tubing is rerun, under pressure. In order to accommodate the large capacity of the wells, it is customary to set three separators, six vent lines and large oil-storage tanks. It is conservatively estimated that the equipment not needed for producing the well currently but which is installed solely for the purpose of establishing large potentials costs the operator at least \$5000 per well—approximately 35 per cent of the cost of equipping a well for production. Such needless expenditure constitutes an economic waste in addition to the gas that is wasted in taking potentials.

MEANING OF PRODUCTIVITY INDEX

A method of measuring the relative ability of wells to produce without open flow that shows considerable promise is the Productivity Index. This method was first suggested by T. V. Moore¹, and has since been

Manuscript received at the office of the Institute Oct. 8, 1936.

* The Carter Oil Co., Tulsa, Okla.

¹ T. V. Moore: *Proc. Amer. Petr. Inst.* (1930) **11** [4], 27.

strongly advocated by many engineers and producers. The method involves measurement of the static, or shut-in, bottom-hole pressure and the bottom-hole pressure while the well is flowing. The productivity index is defined as the barrels of oil per day per pound differential between static and flowing bottom-hole pressure. In determining the index of a well, the well is produced at low rates of production, thus eliminating gas wastage, the possibility of water-coning, and unnecessary oversize expensive equipment required for open-flow potentials. Obtaining the productivity index involves measurement of the pressure differential at the sand face, which measures only the resistance of the sand or producing formation to yield oil, and does not take into account the resistance of the flow string. It therefore reflects the true relative ability of the well to produce. It is a well-known fact that in taking the open-flow potentials of large wells, the size of the casing is an important factor in determining the potential obtained. Two wells may have the same relative ability to yield oil, but if one of the wells has larger casing than the other it will obtain a larger potential.

APPLICATION OF PRODUCTIVITY INDEX

The productivity index has been widely discussed, and engineers are in agreement as to its many advantages, but there has not been sufficient field testing to determine its practicability. Theoretically, all that is necessary to determine the index is to measure the static bottom-hole pressure and then produce the well, measure the production and the flowing bottom-hole pressure, and calculate the productivity index. Actually, it is necessary to measure the bottom-hole pressure at various rates of production in order to eliminate the possibility of errors that may be incurred in determining only one value. When plotting the indices thus obtained, in many instances a different value is obtained for the index at each rate of production. This naturally gives rise to the question as to whether or not the index is a constant with rate of production, or whether we should expect to find a different value for each rate. In order to be able to make practical application of the index in the allocation of production, it should be a constant with rate of production, since if a different value is obtained at each rate it would be extremely difficult to determine at which rate the value of the index should be taken. In order that the index be a constant, the pressure differential must be a straight-line function of the rate of production according to the equation $y = mx + b$ with b equal to zero, y equal to the rate of production and x equal to the pressure differential. The slope of the line m is then equal to the productivity index, and is a constant.

Stanley Herold² indicates that the productivity index defined as the barrels per day per pound pressure differential is not a constant with rate

² S. Herold: *Petr. World* (1935) **32**, No. 6, 48.

of production. He defines two indices, one for reservoirs in hydraulic and volumetric control and one for reservoirs in capillary control. For the first, dividing the rate by the $\frac{1}{2}$ power of the pressure differential should yield a constant index; and for capillary control, dividing the rate by the $\frac{3}{2}$ power of the pressure differential should yield a constant index. However, the writer, in a paper presented at the mid-year meeting of the American Petroleum Institute in May 1935, presented data that indicated that the index arrived at by using either the $\frac{1}{2}$ or the $\frac{3}{2}$ power of the pressure differential did not yield a constant index. The conclusions in that paper were that if the index is properly determined and errors in measurement of production and bottom-hole pressure are eliminated, the index as defined in this paper is a constant with rate of production. Since this is an open question, it is hoped that this paper will stimulate some thought and study on this subject, and that in the near future we shall be able to make practical application of the productivity index in the allocation of production.

Considerable progress has been made in recent years in the development and perfection of bottom-hole pressure gauges. Cooperative work among the several companies has shown that where proper precautions are taken check measurements of bottom-hole pressure may be obtained, both with the same instrument and with two or more instruments, even when the several instruments are of different makes. However, it is also well known that if proper precautions are not taken check results are not obtained. In determining the productivity, it is highly important that the subsurface-pressure gauge be accurately calibrated, and if two or more gauges are used it is important that they be calibrated on the same deadweight tester and also be checked in the well, if comparable results are to be obtained. When determining the static pressure of a well, precautions must be taken to properly prepare the well, the most important factor being the shut-in period prior to measurement of the pressure. While one well may attain its maximum pressure in 4 hr., another may require 24 hr., the period required to reach equilibrium depending on the rate of production prior to closing in the well, the permeability of the producing formation, the physical properties of the reservoir fluid, and other factors. In obtaining the bottom-hole pressure while the well is flowing, it is necessary to permit the well to flow at that rate for a period of time sufficient to allow the reservoir conditions to become stabilized; this again may require only a few hours in one well, whereas another well may require 10 or 20 hours.

Another very important factor in determining the productivity index is to accurately gauge the well's producing rate. While it may be true that the pressure differential is a straight-line function of the rate of production, this condition exists only at the lower rates of production, since at high rates the resistance of flow through the producing formation,

liberation of gas from solution, and other factors are disturbing elements. Even if this were not true, it would still be desirable to produce the well at low rates to prevent undue waste of gas, the possibility of water-coning, and other detrimental factors. Therefore, it is highly important that the well's production be accurately gauged, since a small error may result in considerable error in the value of the index.

These factors are highly important and should be carefully observed, as they may make the difference between accurate and reliable indices compared with erroneous, useless data. It is the writer's experience that in most cases, if not always, productivity indices that are not con-

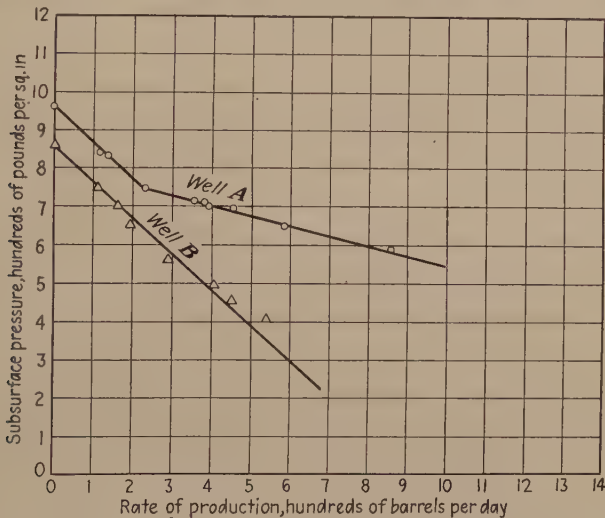


FIG. 1.—TYPICAL DATA OBTAINED IN SOUTH BURBANK POOL.

stant with rate of production are due to errors in measurement of the bottom-hole pressure, or in gauging of the producing rate, or both, and if the data are rechecked, and all possible errors eliminated, a straight-line relationship will be obtained.

TYPICAL DATA

Table 1 and Fig. 1 present typical data obtained on wells in the South Burbank pool. The points for well A fall on two straight lines, while a single straight-line interpretation can be put on all of the points for well B. Since the data at the low rates fall on a straight line for well A, the productivity index is constant at these low rates and hence gives satisfactory results.

Table 1 and Fig. 2 present data obtained on wells in the Keokuk and Lucien pools. The data for well C falls on a straight line, hence yields a constant productivity index. However, the data for well D curve

THE PRODUCTIVITY INDEX

TABLE 1.—*Typical Data*

Subsurface Pressure, Lb. per Sq. In.	Pressure Differential, Lb. per Sq. In.	Rate of Oil Production, Bbl. per Day	Pressure Differential, Bbl. per Day
WELL A, SOUTH BURBANK POOL			
962	0	0	
842	61	120	1.97
838	65	130	2.00
750	121	228	1.88
719	184	362	1.97
718	185	382	2.06
710	193	385	2.00
709	194	394	2.03
697	206	453	2.20
650	253	583	2.30
582	321	858	2.68
WELL B, SOUTH BURBANK POOL			
866	- 0	0	
748	118	107	0.91
705	161	160	0.99
652	214	196	0.92
566	300	288	0.96
494	372	407	1.09
461	405	450	1.11
420	446	539	1.21
WELL C, KEOKUK AND LUCIEN POOLS			
1730	0	0	
1498	232	166	0.72
1317	413	315	0.76
1095	635	470	0.74
950	780	581	0.74
813	917	668	0.73
WELL D, KEOKUK AND LUCIEN POOLS			
1548	0	0	
1403	145	155	1.07
1365	183	240	1.31
1235	313	428	1.37
1118	430	625	1.44
987	561	842	1.49
900	648	977	1.51
WELL E, KEOKUK AND LUCIEN POOLS			
1710	0	0	
1630	80	255	3.19
1488	222	520	2.34
1315	395	772	1.96
1167	543	980	1.80
1058	652	1124	1.72

upward, while the data for well E curve downward, yielding increasing indices in the first case and decreasing indices in the second case, as may be seen in the upper part of Fig. 2. For wells of this type, unless it can be established that the data are in error, and a straight-line relationship can be obtained upon rerunning, endless controversy will result as to which value to use. The rate that yields the highest index for one well

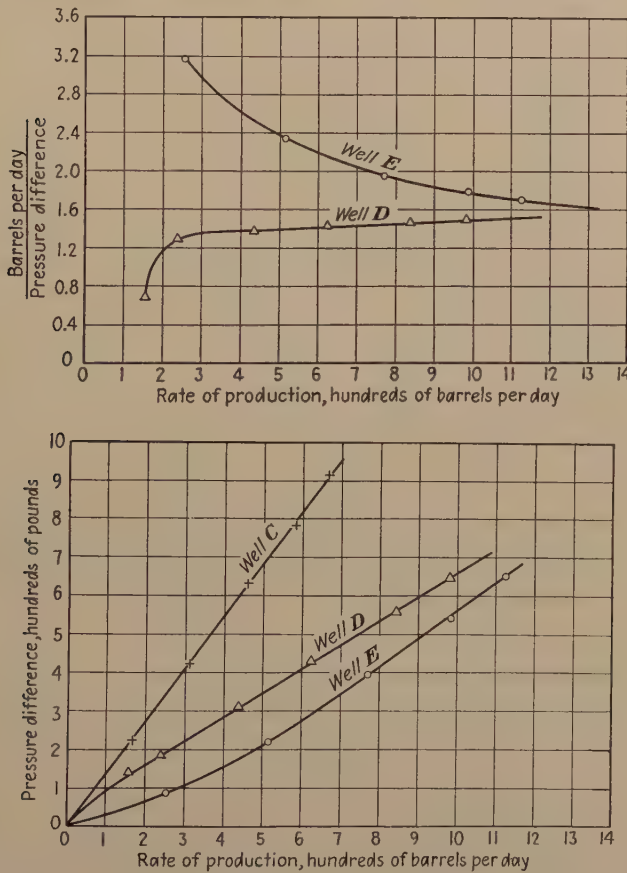


FIG. 2.—TYPICAL DATA OBTAINED IN KEOKUK AND LUCIEN POOLS.

yields the lowest index for the other well. In order to minimize this difficulty, it may be possible to use a modified productivity index—a modification that may be accomplished by applying an exponent to the index, or by the inclusion of static bottom-hole pressure in the allocation formula.

Fig. 3 presents the bottom-hole pressure plotted against rate of production on wells C and E. The data at the high rates fall on a straight line for both wells, although on well E the data are curved at the low rates. If the straight-line relationship for well E at the high rates is

extended to the pressure ordinate, it indicates a static pressure of approximately 1850 lb., compared with an observed value of 1710 lb. Fig. 3 illustrates another method that might be used to employ flowing bottom-hole pressures in the allocation of production without directly using the productivity index, whereby the relative ability to produce is determined by the rate of production at a given bottom-hole pressure. For example,

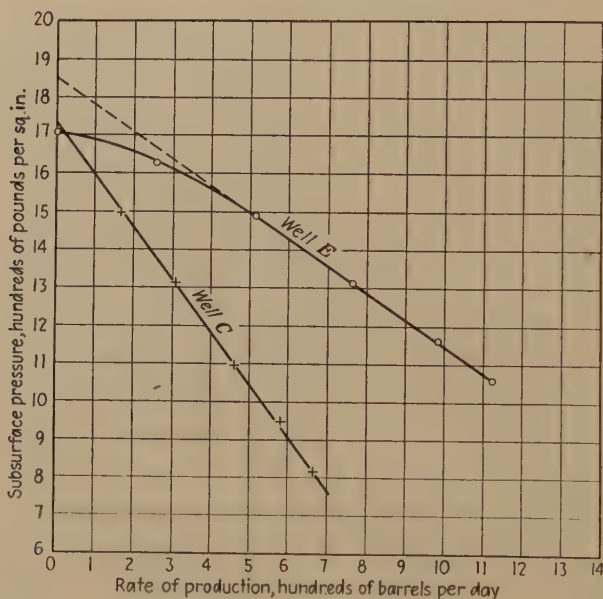


FIG. 3.—BOTTOM-HOLE PRESSURE AND RATE PRODUCTION, ON WELLS C AND E.

if the basic bottom-hole pressure selected is 1400 lb., the potential for well C would be 240 bbl., and well E 635 barrels.

RECOMMENDATIONS

In conclusion, it is recommended that when productivity indices are determined the following points be carefully observed:

1. Do not take pressure or production measurements until the well has been given sufficient time to reach equilibrium conditions. When in doubt as to the period required, obtain pressure-time curves.
2. Accurate measurement of production is just as important as accurate measurement of the bottom-hole pressure. Production measurements should be accurately gauged while the pressure gauge is in the hole, as well as before and after running the gauge.
3. Measurement of the gas as well as oil should be obtained. Often erratic indices are due to high gas-oil ratios at certain rates of production.
4. Every precaution should be taken to calibrate accurately the subsurface pressure gauge.

5. Several pressure measurements should be taken opposite the producing formation to eliminate all possible errors. In thick formations, readings should be taken at several points opposite the producing formation.

6. If the well is tubed but producing through the casing, the pressure measurements should be taken as near the bottom of the hole as possible, since under these conditions pressures in the tubing do not always reflect the pressure in the casing at the equivalent depths.

DISCUSSION

(L. L. Foley presiding)

D. M. COLLINGWOOD,* Dallas, Texas (written discussion).—In many cases we have found that slight errors in measurement of bottom-hole pressures or in oil-production gauges can be blamed for departure from the straight-line relationship between pressure-differential observations and rate of production.

Probably greater accuracy is demanded of the pressure instrument than in other phases of bottom-hole pressure work, particularly in highly permeable reservoirs where the working accuracy of the instrument becomes a high percentage of the relatively low differential.

Precautions to ensure accurate oil gauges are important. It is often advisable to continue the test for a longer period than required for stabilized bottom-hole conditions, because of the inaccuracy of tank gauges over a small interval of time.

Differential-pressure data are frequently misleading when free gas from the reservoir is also being produced with the oil. The free gas may come from an original gas cap open to the hole, from a down-coned gas cap, or from within the oil reservoir itself. Analysis of the gas produced at the surface, together with analyses of bottom-hole samples taken under pressure, permit computation of the nature and volume of the free gas as it moves to the well under the reservoir conditions of pressure and temperature. This volume may be expressed in terms of equivalent barrels of oil and included in the production gauge used to determine the productivity index. However, even then the index may not be a constant with rate of total production so figured. This, no doubt, is because the resistance to the passage of gas is less than the resistance to the passage of oil, volume for volume, through a sand of given permeability.

Should the productivity index be used for proration purposes and it is further considered equitable and desirable that wells in a reservoir of more or less uniform permeability be permitted to produce with the same daily volumetric displacement from the reservoir, it would seem desirable to formulate a factor that would be a function of both volume and viscosity free-gas-to-oil ratios. This factor, proposed only for conditions of viscous flow, when applied to the total figure for oil and gas production, should give an equivalent productivity index which will be a constant with rate of total oil and gas production, or volumetric displacement.

* Sun Oil Co.

Experiments on Flow of Fluids through Sands

By F. B. PLUMMER,* MEMBER A.I.M.E., AND J. S. WOODWARD†

(Fort Worth Meeting, October, 1936)

THE measurement of the rate of flow of liquids through sands dates back to 1856, when H. d'Arcy^{6†}, a French physicist, carried out his classic experiments on the flow of water through sand layers. The earliest recorded data on relationships of pressure to flow of fluids through porous rocks in this country are those of Newell²³ in 1885. The first comprehensive studies of flow were made in 1898 by King¹⁵, who measured the rate of flow of water and air through consolidated and unconsolidated sands and published the results. From 1900 to 1920 there appears to have been little interest in permeability.

In 1920 the increase in demand for oil led the U. S. Bureau of Mines to begin a series of experiments to determine subsurface relationships of oil and water and the characteristics of their flow. Mills¹⁸ studied the relationship of flow of liquids to texture and structure of the sands, and Melcher¹⁷ in 1925 made a quantitative study of effect of changes in pressure on rate of flow of crude oil through Oklahoma oil sands. Since 1930 the importance of flow measurements to production of oil and gas has been emphasized by a large number of excellent investigations. Among these the works of Fettke^{9,10}, Barb^{1,2}, Cloud⁵, Nutting²⁴⁻²⁷, Botset⁴, Nevin²², Tickell^{32,33}, Fancher, Lewis and Barnes⁸, Moore, Schilthuis and Hurst¹⁹, and Wyckoff, Botset and Muskat³⁷⁻³⁹ have contributed much to our knowledge of the technique of permeability measurements and to the laws of liquid and gas flow through porous sands. The application of their work has led to the establishment of laboratories for measuring the permeability and porosity of oil sands by most of the large companies. All the investigations, except those of Wyckoff, Botset and Muskat, and Moore, Schilthuis and Hurst deal with linear flow; that is, flow in a more or less straight line through a given cross-sectional area of sand.

Three years ago, at the University of Texas, experiments were started to measure radial flow of liquids through sands; that is, flow from all directions toward a central opening—the conditions that operate in a

Manuscript received at the office of the Institute Sept. 8, 1936.

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sand when oil from the surrounding reservoir flows to the well. The experiments were carried out successfully, and the mathematics involved in computing radial flow were worked out by Dr. Sidon Harris²⁸. In the same year, Wyckoff, Botset, and Muskat³⁹ published descriptions of their equipment for measuring both linear and radial permeability, worked out a new formula for radial flow somewhat simpler than the one used by Dr. Harris, and applied their formula to determine the rate of production of East Texas oil wells. Their work deserves much credit and has been of much help in our investigations.

METHOD OF MEASURING RADIAL FLOW

The method consists of cutting 4-in. cores with a core drill, then drilling a $\frac{3}{4}$ -in. hole vertically through the center. The cores are placed

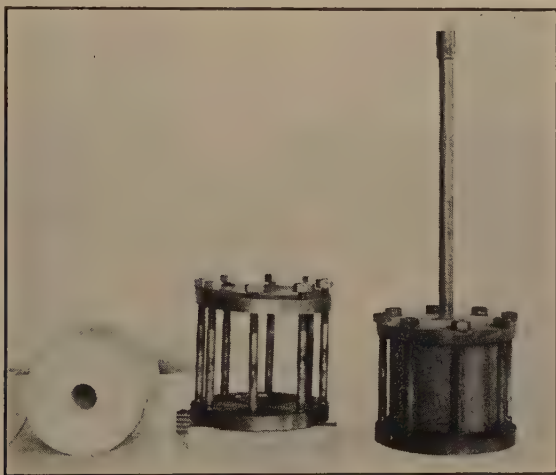


FIG. 1.—CORE HOLDERS AND CORES FOR MEASURING RADIAL FLOW OF CONSOLIDATED SANDS.

in core holders (Fig. 1) and the core holders inserted into a pressure-cylinder. A 16-in., rectangularly shaped tank is placed inside the cylinder and filled with oil until the cores are completely immersed. Then the cylinder head is clamped on and bolted in place. Brass tubes $\frac{1}{4}$ in. in diameter are inserted into the core holders and connected into the "well heads" of the holders by means of a screw connection. The tubes lead out into graduated receivers in which the oil that flows through the cores is measured (Fig. 2). Pressure is applied to the cylinder from a small compressor, and the differential pressure between the reservoir and producing side of the sand is measured by a manometer. The time required to flow 500 c.c. of oil into the receivers is recorded by a stopwatch. The viscosity of the oil in the receivers is measured with an

Ostwald pipette. Radial permeability is calculated by the following formula worked out by Wyckoff³⁹ and his associates:

$$K = \frac{U \cdot Q \log_e \frac{r_1}{r_2}}{2\pi t(P_1 - P_2)}$$

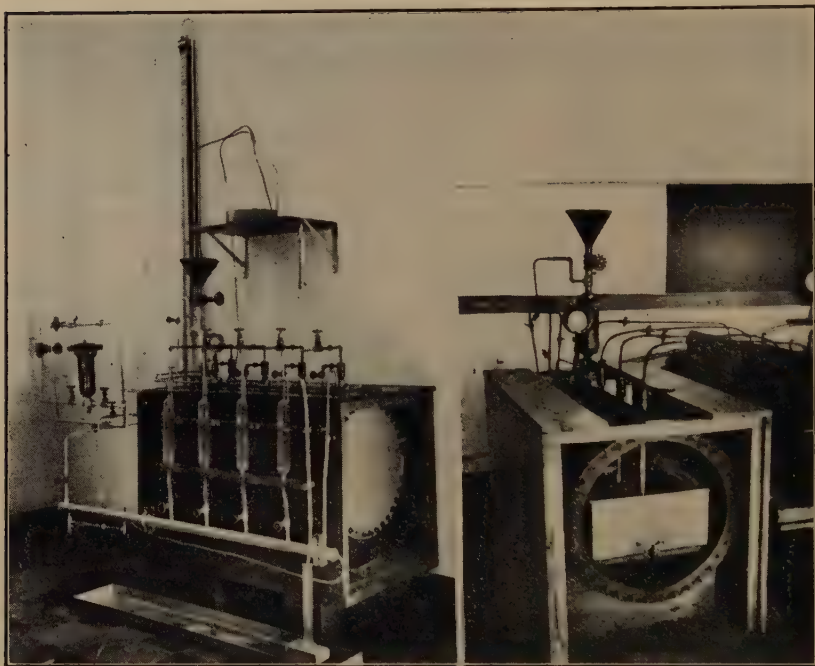


FIG. 2.—COMPLETE APPARATUS FOR MEASURING RADIAL FLOW.
a, cylinder closed; b, cylinder open, showing fluid tank.

Smaller cores can be used but the results are not quite so representative.

K = permeability, darcys,

U = viscosity, centipoises,

Q = rate of flow, c.c. per second,

r_1 = diameter of core, cm.,

r_2 = diameter of central hole, cm.,

t = thickness of core, cm.,

P_1 = pressure of reservoir, atmospheres,

P_2 = pressure at bottom of hole, atmospheres.

From this:

$$Q = \frac{2\pi \cdot T \cdot K \cdot (P_1 - P_2)}{U \cdot \log_e \left(\frac{r_1}{r_2} \right)}$$

COMPARISON OF LINEAR AND RADIAL PERMEABILITY

The standard methods of determining linear permeability are simpler and the working time is shorter than the methods and operating time for radial permeability. The results obtained with the linear-permeability equipment are as accurate and as useful as those for radial permeability. The radial-permeability apparatus, however, furnishes a means of investigating flow through sand and a wider variety of conditions, diversity of liquids, gases and mixtures and permits a greater control

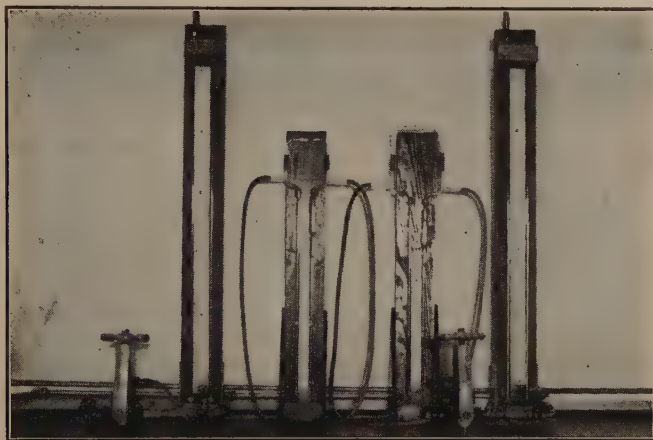


FIG. 3.—APPARATUS USED AT UNIVERSITY OF TEXAS FOR MEASURING LINEAR FLOW (DESIGNED BY FANCHER, LEWIS AND BARNES).

of experimental conditions than the linear apparatus. Table 1 shows a comparison of typical results of measurements made of the same sand by the two methods. The $\frac{5}{8}$ -in. samples were cut out of the cores in a horizontal direction and the linear permeability was measured in an apparatus similar to that described by Fancher, Lewis and Barnes⁸ and illustrated in Fig. 3. Dry air was used as the flow medium and all ordinary precautions were exercised to obtain accurate measurements. The results are shown in Table 1.

TABLE 1.—*Comparison of Radial and Linear Permeability*

Sand	Radial Permeability	Linear Permeability	Difference
Queen City.....	0.183	0.110	0.073
Graford, upper.....	0.0137	0.0139	0.0002
Graford, lower.....	0.110	0.166	0.056
Paluxy.....	0.518	0.695	0.177

A typical example of linear-permeability measurements of samples taken out of same 4-in. core is: sample No. 1, linear permeability 0.110;

sample No. 2, 0.1092; sample No. 3, 0.138; sample No. 4, 0.082; maximum difference, 0.056.

The results except for the Paluxy sand are quite close; in fact, closer than one would expect, considering the wide difference in size between the small chunk used in the linear-permeability apparatus and the large cores used in the radial apparatus. In fact, the variation in the permeability of three different samples taken from the same 4-in. core is greater than most of the variation between the results obtained by the linear and radial methods.

METHOD OF MEASURING PERMEABILITY OF UNCONSOLIDATED SANDS

The measurement of the permeability of uncemented sand has been desirable; first, because many Gulf Coast oil sands are so friable that it is

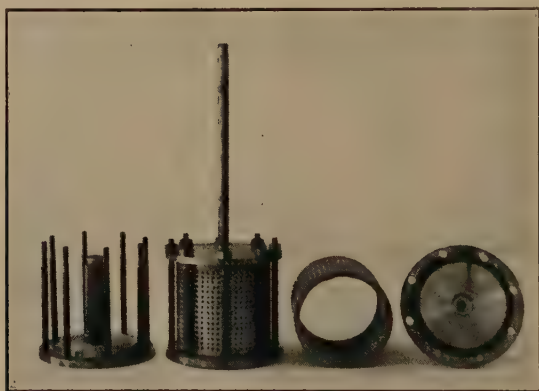


FIG. 4.—CORE HOLDERS FOR MEASUREMENT OF RATE OF FLOW THROUGH UNCONSOLIDATED SANDS.

difficult or impossible to get samples that can be measured in the usual way; second, because the preparation of 4-in. consolidated cores with central drill holes is tedious and time-consuming. Much time and work can be saved in many flow experiments if loose sands can be used. The holders for loose sand consisted of two perforated brass cylinders 4 in. long set in grooved brass plates and clamped with $\frac{3}{8}$ -in. steel bolts and nuts (Fig. 4). The inner cylinder is one inch in diameter and covered on the outside by 60-mesh brass screen. The outer cylinder is 4 in. in diameter, and contains on its inside a close-fitting cylindrical 60-mesh brass screen. The two cylinders with their screens are set on the brass plate containing the tie-down bolts. The sand to be measured is poured in, saturated with the fluid to be used in the measurement, the cylinder completely filled, the upper plate placed in position and drawn down until the sand is compressed as much as possible between the two plates. If the upper plate engaged the cylinder edge, it is removed and the cylinder filled again with sand and recompressed. Two or three trials

are generally sufficient to be certain that the sand is compressed as much as the bolts and brass cylinders will allow. The cylinders are then placed in the steel pressure chamber and the permeability measured in exactly the same way as for that of solid cores.

COMPARISON OF PERMEABILITY OF UNCONSOLIDATED AND SEMICONSOLIDATED SAND

The method of measuring the permeability of unconsolidated sand was tested, first, by measuring a number of samples of the same sand; and, second, by measuring the permeability of cores of semiconsolidated sand, and comparing the results with pulverized samples of the same core measured in the perforated and screened containers. (Fig. 5) shows the results obtained from typical samples of Travis Peak, Paluxy, and Queen City Marine sand.

TABLE 2.—*Permeability of Sands from Paluxy, Travis Peak and Queen City Formations*

	Permeability, Darcys		Difference
	Unconsolidated	Semiconsolidated	
Paluxy.....	0.63	0.58	-0.122
Travis Peak.....	5.7	4.2	-1.5
Queen City.....	1.142	0.883	-0.259

Kerosene was used as the liquid. The unconsolidated sand was completely disintegrated and dried before it was put into the core holders. A trace of the sand passed through the screens at the beginning of the liquid flow. After a minute, no sand was produced in any of the tests.

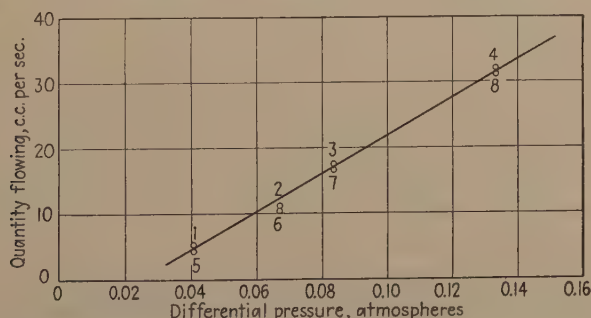


FIG. 5.—PERMEABILITY OF TYPICAL UNCONSOLIDATED SAND.

The difference between the semiconsolidated and unconsolidated sand averaged 0.627 darcys. The greatest difference is 1.5 darcys and the smallest difference is 0.122. The semiconsolidated sand was just hard enough to be cut and several broke down during the process. Neverthe-

less, in order to hold together at all it must be slightly cemented. Therefore, it should be less permeable than the unconsolidated. The results show this to be true, and the presence of cementing material in the sand lowers its permeability (Fig. 6).

EFFECT OF SIZE OF HOLE ON RATE OF FLOW

Wyckoff, Botset and Muskat³⁹ showed that the permeability varied as the natural log of the ratio of the radius of the drainage area divided

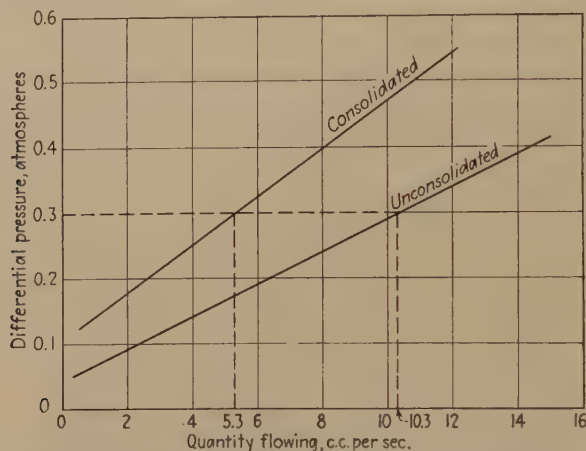


FIG. 6.—COMPARISON OF UNCONSOLIDATED AND SEMICONSOLIDATED SAND OF SIMILAR TEXTURE.

by the radius of the hole in the sand. Theoretically, therefore, if the radius of a 0.9-cm. hole in a 4-in. core is doubled, and all other factors are kept constant, the rate of flow is increased 43 per cent. This effect was tested out in the radial-permeability apparatus as follows: First, holes 0.9 cm. in diameter were cut in four different typical oil sands. The cores were placed in the core holders and the permeability carefully measured. Then the holes were enlarged to 2.2 cm., a little more than twice the first size, and the permeability again measured. The cores were again removed from the holders and the holes reamed out to 3.75 cm., or a little more than three times the original size and the permeability measured for the third time (Fig. 7). A comparison of the results is shown in Fig. 8 and Table 3.

TABLE 3.—Effect of Increasing Size of Hole on Rate of Flow in Edwards Oolitic Limestone at a Pressure of 3 Atmospheres

Diameter of Hole, Cm.	Production, C.c. per Sec.	Increase, Per Cent Cumulative
0.9	0.2	
2.2	0.305	52.5
3.75	0.49	145.0

The results are a little larger than they should be theoretically, because the calculations are not corrected for the shorter distance traveled by the fluid in flowing from the periphery of the core to the larger hole. This amounts to an increase of about 10 per cent. The results show clearly that the larger the hole the larger the production of the well, and they indicate that where large potentials are desirable underreaming to increase the size of the hole in the sand is good practice.

EFFECT OF DEPTH OF PENETRATION OF SAND ON RATE OF FLOW OF OIL

All field men know that the deeper a well is drilled into a sand, other factors remaining the same, the larger the production. Yet few figures are

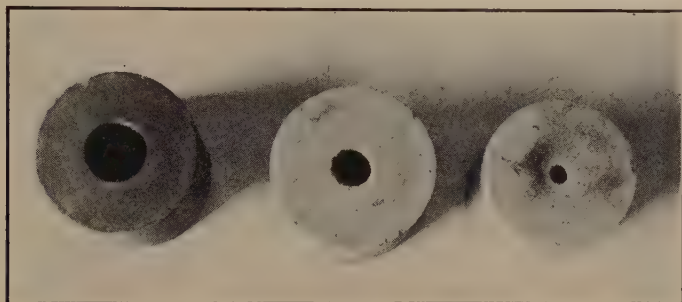


FIG. 7.—CORES WITH HOLES OF DIFFERENT SIZES.

available showing quantitatively just what is the rate of increase per foot of depth penetrated. Experiments were carried out showing the effect of penetration on the flow of oil through the 4-in. cores. Four typical oil-sand cores were selected and drilled exactly one inch with $\frac{5}{8}$ -in. drills. The cores were placed in the core holders and the permeability measured. Then the holes were drilled 2 in. deep, the cores thoroughly cleaned and the permeability measurements repeated. Next the holes were all deepened to 3 in., and then to 4 inches, and the respective permeability measurements determined after each deepening. The results of the increase in depth on the rate of flow is shown in Table 4 and in the graphs in Fig. 9.

TABLE 4.—*Effect of Increased Penetration on Rate of Flow in Pennsylvanian Sandstone at $2\frac{1}{2}$ Atmospheres Pressure*

Penetration, Per Cent	Depth of Hole in Sand, In.	Production, C.c. per Second	Increase, Per Cent Cumulative
25	1	0.235	
50	2	0.49	108
75	3	0.64	172
100	4	0.80	240

The rate of increase of flow through oil-sand cores with increase in penetration is an exponential function, which may be represented by a simple empirical equation or solved by means of a graph. Additional data, especially field observations, are desirable before establishing a final solution.

It would be extremely interesting to measure the actual rate of flow of an oil well at different penetration depths and to ascertain the actual increase in production of oil. The laboratory results probably would be more applicable if much larger diameter cores could be used. They indicate, however, that penetration is an important factor in the potential production of an oil well.

EFFECT OF PRESENCE OF WATER ON FLOW OF OIL THROUGH CORES OF OIL SANDS

The radial permeability apparatus is adapted well to the study of the effect of oil-water mixtures on total oil recovery through cores. A number

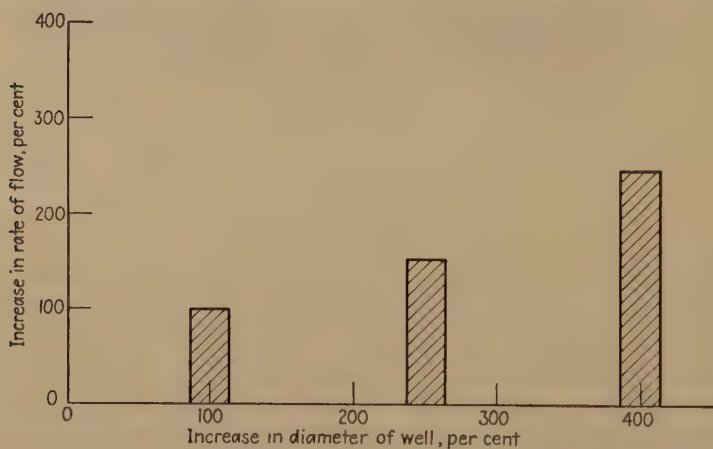


FIG. 8.—EFFECT OF SIZE OF HOLE UPON RATE OF FLOW, TAKING PRODUCTION FROM SMALLEST HOLE AT 100 PER CENT.

of experiments have been carried out to study the flow of mixtures of oil and gas and oil and water through sands. One example will serve to illustrate the experiments. Cores of four oil sands of different permeabilities were placed in the pressure cylinder of the permeability apparatus, and the permeability of each measured with kerosene in the usual way. Then while the cores were still thoroughly saturated with kerosene, the oil in the apparatus was all removed and replaced by a mixture of exactly one-half kerosene and one-half water. The water-kerosene line reached to exactly the halfway line on the sides of the cores (Fig. 10). Then the pressure was turned on and the oil allowed to produce, with the results shown in Table 5.

The results show that at first the capillary action of the water on the oil operates to drive some of the oil out of the finer pores into the larger

passageways and that the cores produce more oil than water. This continues for about 10 hr. in the finest grained sand. After 24 hr. the capillary drive is complete, and the oil-water ratios continue uniform as long as the fluids are produced. The ratios of oil to water vary with the

TABLE 5.—*Flow of Kerosene-water Mixtures through Sands (at All Pressures)*

	Percentage of Flow					
	15 Min.		60 Min.		24 Hr.	
	H ₂ O	Oil	H ₂ O	Oil	H ₂ O	Oil
Pennsylvanian sand No. 1 from Possum Kingdom Bend.....	9.6	90.4	9.6	90.4	21	79
Pennsylvanian sand No. 2 from Possum Kingdom Bend.....	9.6	90.4	9.6	90.4	10	90
Pennsylvanian sand No. 3 from Mineral Wells.....	21.2	78.8	46.0	54.0	48	52
Cretaceous oolitic limestone from Cedar Park.....	0	100.0	10.0	90.0	91	9

permeability. The finest grained, least permeable cores produce the greatest amount of water, as shown by Table 6.

TABLE 6.—*Relation of Water-oil Ratio to Permeability and Porosity of Cores*

	H ₂ O, Per Cent	Oil, Per Cent	Permeability, Darcys	Porosity, Per Cent
Pennsylvanian sand No. 1.....	21	79	0.146	23.5
Pennsylvanian sand No. 2.....	10	90	0.0755	22.4
Pennsylvanian sand No. 3.....	40	60	0.615	36
Cretaceous oolitic limestone.....	91	9	0.00227	31.05

The oil-water ratios can be changed in the same cores by decreasing the surface tension of the water by addition of a surface-tension breaker and by pinching in the flow so that the production time is reduced to a minimum. Further experiments are now under way to determine conditions under which the largest percentage of oil is obtained.

SUMMARY

The experiments described in this paper show that laws of radial flow can be successfully demonstrated by using small cores in a pressure cylinder. The effect of various factors that influence production can be studied and better understood. Thus the effect of amount of compaction, amount of cementation, texture of sands, depth of penetration, and size of hole on the rate of flow of fluids through sands is strikingly brought out. But most interesting, perhaps, is the opportunity to demonstrate the

effect of size of pore space on oil-water ratios, the effect of different pressures on oil-water ratios, and the effect of rate of production on oil-water ratios. It is planned to extend these experiments to include studies of the flow of mixtures having different surface and interfacial

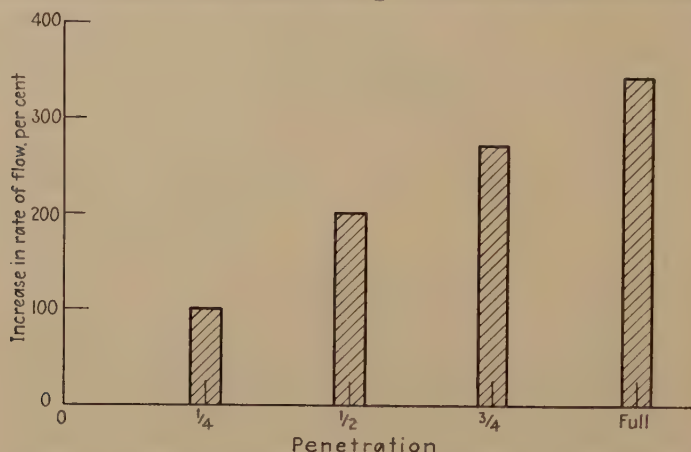


FIG. 9.—EFFECT OF DEPTH OF PENETRATION UPON RATE OF FLOW, TAKING INITIAL PENETRATION AT 100 PER CENT.

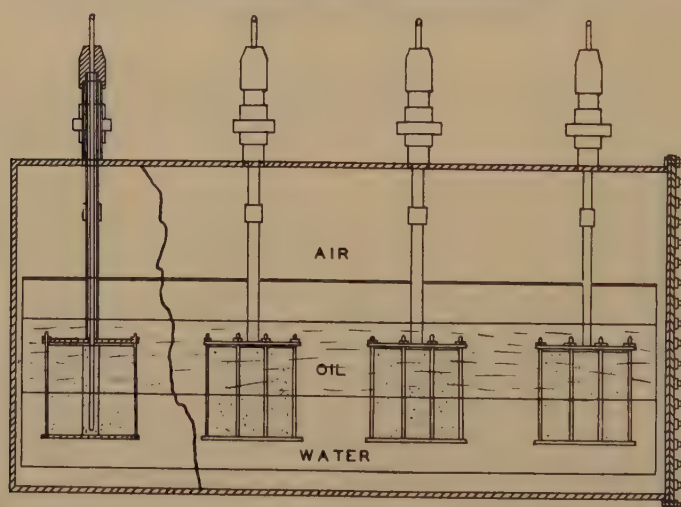


FIG. 10.—DIAGRAM OF CORES AND CORE HOLDERS SHOWING POSITION OF OIL, WATER AND CONTACT LINE.

tension, the flow of emulsions and the effects of various types of cleaning solutions on oil production.

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Chapter III. Stabilization

Can the Rule of Capture Be Rationalized?

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(New York Meeting, February, 1937)

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THE A.I.M.E. Stabilization Committee was named in 1932 to ascertain whether some practical substitute could be devised for the Rule of Capture, which was generally credited with being the major cause of instability in the Petroleum Industry. After considerable intercommittee correspondence a letter was received from E. DeGolyer under date of Jan. 25, 1935, in which he discussed the possibility of modifying rather than discarding the Rule of Capture. He summarized his proposal as follows:

Manuscript received at the office of the Institute Nov. 23, 1936.

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The one thought that I want to leave with you is that possibly we are wrong in supposing that the destruction of the Rule of Capture is a prerequisite to correcting the evils of the production end of the business. It may be that it is as good a base as any other upon which to build decent regulations.

Mr. DeGolyer's letter was circulated among members of the Committee, with the result that the issue set forth in the title of this paper was developed. The material received in reply is too voluminous to reproduce here. We can do no more than attempt to apply to it the mechanical, economic, political and legal tests proposed by Dean Roscoe Pound, of Harvard Law School. This paper in no manner represents the considered conclusion of the committee, but is instead merely an attempt by its chairman to provide an outline on which to develop a discussion of the subject. Many helpful criticisms were received for which appreciation is expressed.

DEFINITIONS AND REMEDIES

Robert E. Hardwicke, in the "Rule of Capture and Its Implications as Applied to Oil and Gas," described the Rule of Capture and its antithesis as follows¹:

Disregarding refinements, and apart from implications or incidental corollaries, and reduced to its fundamentals, the Rule of Capture may be stated as follows: The owner of a tract of land acquires title to the oil or gas which he produces from wells drilled thereon, though it may be proved that part of such oil or gas migrated from adjoining lands. The antithesis of the Rule of Capture is: The owner of a tract of land owns the oil and gas in place and should such minerals migrate to a neighbor's land and be produced from wells thereon, title would not vest in the neighbor, but, to the contrary, the migrating oil or gas, or at least an amount equal to that which migrated, could be recovered by the true owner.

This is an exact, comprehensive, and concise statement regarding ownership to oil and gas in the United States. It brings out in bold relief the fundamental characteristics of two inherently different theories of that ownership. Law is of value to society only in the results that it produces. Confusion has resulted in the Oil Industry, and the Law of Oil and Gas has been made an incomprehensible jumble through the efforts of courts to reconcile and combine these two inherently conflicting theories of ownership. The result is a hybrid, reflected in waste and instability of the Oil Industry.

In five, or possibly six, states it is held there can be no such thing as Ownership of Oil and Gas in Place and that the owner of land possesses only the exclusive right to reduce to possession oil and gas that may be recovered through wells drilled on his land. In ten states Ownership in Place is recognized. However, all oil men know that as a practical oper-

¹ *The Texas Law Review*, XIII, No. 4.

ating problem exactly the same rule is applied in every state without distinction, and that the rule which is used is the so-called Rule of Capture.

This incongruity in those states where Ownership in Place is said to prevail can be explained away by no other sensible theory, if words mean anything in a practical way, than that the best evidence of the content of land is what comes out of it. The fallacy of that assumption can be illustrated by quoting the opinions out of which originated the strange mass of inconsistency now known as Oil and Gas Law.

In 1889 the Supreme Court of Pennsylvania in the case of *Westmoreland Natural Gas Company vs. DeWitt*² said:

Water and oil, and still more strongly, gas may be classed by themselves, if the analogy be not too fanciful, as minerals *ferae naturae*. In common with animals, and unlike other minerals, they have the power and the tendency to escape without the volition of the owner. Their 'fugitive and wandering existence within the limits of a particular tract was uncertain,' as said by Chief Justice Agnew in *Brown vs. Vandergrift*, 80 Pas. St. 147, 148. They belong to the owner of the land and are part of it, so long as they are on or in it, and are subject to his control; but when they escape and go into other land, or come under another's control, the title of the former owner is gone. Possession of the land, therefore, is not necessarily possession of the gas. If an adjoining, or even a distant, owner drills his own land, and taps your gas, so that it comes into his well and under his control, it is no longer yours, but his.

What a weird conception of ownership! Now you see it! Now you don't! No wonder Henry M. Bates, Dean of Michigan Law School, when discussing in 1934 the practical operation of that conception of ownership after a half century of experience with it, said³, "This in itself violates any sane theory of property rights."

In 1897 the Supreme Court of Ohio in *Kelly vs. Ohio Oil Company*⁴ said:

Whatever gets into the well belongs to the owner of the well, no matter where it came from. In such cases the well and its contents belong to the owner or lessee to the land, and no one can tell to a certainty from whence the oil, gas, or water which enters the well came, and no legal right as to the same can be established or enforced by an adjoining landowner. . . . While it is generally supposed that oil is drained into wells for a distance of several hundred feet, the matter is somewhat uncertain, and no right of sufficient weight can be founded upon such uncertain supposition to overcome the well-known right which every man has to use his property as he pleases, so long as he does not interfere with the legal rights of others. Protection of lines of adjoining lands by the drilling of wells on both sides of such lines affords an ample and sufficient remedy for the supposed grievances complained of in the petition and supplemental petition, without resort to either an injunction or an accounting.

It is conceivable how a court in light of the meager knowledge of the actions of reservoir content in the year this opinion was written could have

² 130 Pas. 235, 18 Atl. 724.

³ See extended analysis by Dean Bates on page 149.

⁴ 57 Ohio State 317, 49 N.E. 399.

made such a statement. But for a court or lawyer in the year 1937, in light of the knowledge of reservoir content action existing on the latter date, to proclaim solemnly the same doctrine does not inspire respect for the law or its agencies.

Finally, in 1907 the Supreme Court of Pennsylvania, with these two opinions and others like them as a foundation, proclaimed in *Bernard vs. Monongahela Gas Company* the legal standard of cooperation among neighbors in a common pool that has since shaped the morals of the Oil Industry. Its chief characteristic is that it removes from property rights in oil and gas the protection against despoliation by others that the law has given to property from time immemorial. This is considered to be the leading case in defining the Rule of Capture, and is invariably cited as an authority in connection with any discussion of that rule. The following excerpt, quoted very frequently, is a landmark in Oil and Gas Law⁵:

An oil or gas well may draw its product from an indefinite distance and in time exhaust a large space. Exact knowledge on this subject is not at present attainable, but the vagrant character of the mineral and the porous sand rock in which it is found and through which it moves fully justify the general conclusion we have stated above and have led to its general adoption by practical operators. 'The right of every landowner to drill a well on his own land at whatever spot he may see fit' certainly must be conceded. If, then, the landowner drills on his land at such a spot as best subserves his purposes, what is the standing of the adjoining landowner whose oil or gas may be drained by his well? He certainly ought not to be allowed to stop his neighbor from developing his own farm. There is no certain way of ascertaining how much of the oil and gas that comes out of the well was when *in situ* under this farm and how much under that. What, then, has been held to be the law? It is this, as we understand it, every landowner or his lessee may locate his wells wherever he pleases, regardless of the interests of others. He may distribute them over the whole farm or locate them only on one part of it. He may crowd the adjoining farms so as to enable him to draw the oil and gas from them. What, then, can the neighbor do? Nothing; only go and do likewise. He must protect his own oil and gas. He knows it is wild and will run away if it finds an opening and it is his business to keep it at home. This may not be the best rule; but neither the legislature or our highest court has given us any better. No doubt many thousands of dollars have been expended 'in protecting lines' in oil and gas territory that would not have been expended if some rule had existed by which it could have been avoided. Injunction certainly is not the remedy.

Courts are necessarily compelled to base their decisions on precedents. In early America the vagaries of a calf browsing through the virgin forest were said to have started a sheep trail that became a path, then a road, and finally the street of a great city. That is the history of the Oil Industry. Trial lawyers are compelled to accept the law as it is, sometimes finding consistencies where none exist. Society, however, is interested only in economic and social results. It is a function of government to straighten legal highways when they lead to absurd results.

⁵ 216 Pa. 362, 65 Atl. 801.

Mr. Hardwicke's statement clearly defines two conflicting theories of ownership. The first is the Capture Rule that now applies to oil and gas and a few other items, either inexhaustible or nonessential. The second theory so aptly described by him as "the antithesis of the Rule of Capture" is the customary rule of ownership applied generally to all other tangible things classified as property. In popular parlance, when applied to oil, it is known as "Ownership in Place." The term Ownership in Place shall therefore be used throughout this paper when that theory is being designated.

Economic pressure is compelling the Oil Industry to straighten out its processes. Originally, there were three schools of thought regarding that straightening procedure:

1. Those who contended that the State, except by Constitutional amendment, had no power to change the rule as laid down in *Bernard vs. Monongahela Gas Company*, quoted above.

2. Those who contend that the Rule of Capture is subject to regulation and modification under the ordinary police power of the State and as such is the only logical and practical means of administering the Law of Oil and Gas.

3. Those who contend that the Rule of Capture, regardless of any regulation that might be imposed upon it, has certain inherent characteristics that make it incapable of adaptation to changing concepts of good production practice and that it should be discarded gradually as an ownership concept in favor of Ownership in Place.

Very early in the Proration era, the first contention became a live issue, but the State and Federal courts uniformly ruled against it, so that it is no longer an issue, except as a half-century of practice leaves its influence on public opinion and molds public attitudes. The second suggested course is the one now in most general favor and is in universal application throughout the United States. However, Proration under that principle is becoming unduly burdensome. Waste of oil and gas is being perpetuated, and government supervision of detail is promoted by it. It leaves much to be desired as an aid to Conservation and Stabilization.

The symposium which this paper is designed to promote will discuss the relative merits of the second and third proposals. When foundations are being rebuilt, as is now taking place in the Oil Industry, there is little justification in substituting another foundation equally unsound.

DEAN POUND'S TESTS

Dean Roscoe Pound of Harvard Law School analyzed this issue as follows⁶:

⁶ *Trans. A.I.M.E.* (1935) 114.

I would say the subject is one requiring consideration from a mechanical, an economic, a political, and a legal standpoint. If you are able to work out a program that is mechanically feasible, that is economically advisable, and which seems to your judgment to be politically wise, you will not have very much trouble in the end in inducing the courts of today to find that it is legally sound.

No doubt the converse of Dean Pound's analysis is equally true. If the program is mechanically not feasible, economically inadvisable, and politically unwise, we should not have very much trouble in the end in convincing agencies of government today that it is legally unsound.

The remainder of this paper shall be devoted to testing out both the Capture Rule and Ownership in Place by the standard given to us by Dean Pound. In this comparison the term "Capture Rule" shall imply the rule as defined in *Bernard vs. Monongahela Gas Company*. In several states that rule has been temporarily modified to some degree since the beginning of Proration, but there is no uniformity about that modification, nor is there any assurance such modification will remain beyond the period that Proration is applied. In any event, in all cases the inherent characteristics of the Capture Rule remain, and to that degree the influences of the Capture Rule that are described in the comparison will make themselves felt. When the term "Ownership in Place" is used, it shall signify the antithesis of the Capture Rule as described by Mr. Hardwicke.

I. Mechanically Feasible Test of the Capture Rule

Two major objectives are at all times present in the production of oil and gas. They are:

1. Efficient extraction of the reservoir content produced at the time and rate society needs it; and
2. Equitable distribution of that reservoir content and the market therefor among its respective owners.

If either of these two objectives is not attained, then legal, economic, or political instability is created in the Industry. Attainment of both simultaneously is impossible under operation of the Capture Rule for reasons that will appear presently.

In the typical virgin oil and gas pool, before its content has been disturbed, gas, oil, and water, under great pressure, are found together in the reservoir, with gas occupying the high points, oil the intermediate space, and water the space immediately below. Thus on one side of the oil is the pressure of compressed gas, and on the other side is the pressure of a head of water. Under these circumstances, if a hole is drilled into that part of the reservoir occupied by oil, the behavior of these three fluids under great pressure is to drive the oil through the "sand" to and out of the well. If a hole is drilled into that part of the reservoir occupied

by gas or water, then that product will escape without moving oil before it into the well.

M. Albertson, petroleum engineer, recently listed the factors that determine recovery from a reservoir, as follows⁷:

1. Quantity of oil in the productive formation.
2. Energy available to move oil to the well.
3. Loss of energy other than in movement of oil.
4. Efficiency with which energy is consumed in moving oil to well.
5. Loss of oil and gas due to leakage from reservoir.

Fortunately, energy to do this work is stored in the virgin reservoir, available at no cost, provided it is conserved and controlled. In some pools free gas does not exist, in which case energy is derived from encroaching water and dissolved gas; in other pools encroaching water is absent and energy is derived from free and dissolved gas; in most pools a combination in some ratio of both sources of energy prevails; but in every pool, whether energy be derived from water, compressed gas, or both, the principle of expulsion from the "sand" remains the same. Conservation and control of reservoir energy is therefore essential to efficient recovery of reservoir content. Without it recovery through drilled wells would be impossible.

In one "exhausted" pool known to the writer, cores from the sand indicated 93 per cent of the original oil content of the sand remained there, lost to recovery through early exploitation of the gas content of the reservoir for domestic consumption in near-by cities. The gas would have been equally valuable for domestic consumption after utilizing its energy content in recovering oil from the common reservoir in which both were contained.

John Suman, petroleum engineer, summarized all these recovery principles in the following cryptic remark: "Efficient recovery methods consist in catching oil in the reservoir between the gas and water and squeezing Hell out of it."

Sir John Cadman, president of Anglo-Persian Oil Co., described the result of applying these principles to a pool in Persia to be: "In that particular oil field all that has to be done now is to open the necessary number of valves by means of which the production of crude can from day to day or from hour to hour be regulated to our requirements to a nicety, just as regularly and accurately as when one turns on the water for one's bath."

It is clear from these various summarizations that the wells through which oil and gas are recovered must be located with respect to the content of the reservoir rather than with respect to the boundary lines of surface ownership. Many tracts of land overlying productive parts of

⁷ *Trans. A.I.M.E.* (1936) 118.

the field would be unsuited for well locations; hence, under the recovery principles summarized by Messrs. Albertson, Suman and Cadman, no wells would be drilled on those tracts.

In that event objective No. 2 would be sacrificed because under the Capture Rule the owner of land does not in reality acquire title to the oil and gas in his land until he brings them out through wells drilled on his land. Instead, they would become the property of the adjacent owner, whose land is better located for efficient extraction.

When State proration agencies attempt to promote both Stabilization and efficient recovery through imposing rules and regulations that require low gas-oil ratios, they penalize the owner of high gas-oil ratio tracts, since they do not permit him to capture the content of his own land. He thereupon sues to restrain the Proration commission on the theory that his property is being confiscated, and the court, upon proper showing, pronounces the Proration order invalid. Public opinion does not condone confiscation of individual rights, particularly if they belong to small owners.

If equitable allocation and the efficient type of extraction suggested by Messrs. Albertson, Suman and Cadman are both to be attained, it is obvious that some means must be found whereby the owners of high gas-oil ratio tracts of land do not lose title to the oil and gas content of their land if it is brought out through wells drilled on the land of another.

From these facts it is clear that attainment under the Capture Rule of both objectives simultaneously is not mechanically possible. Therefore, the Capture Rule does not satisfy the mechanically feasible test.

The Mechanically Feasible Test of Ownership in Place

Methods of allocating oil and gas to its respective owners under the Ownership in Place rule fall into two distinct classes, the choice of which should be left to determination of the owners in any given pool or prospective pool as indicated by a majority vote based on a procedure designed to protect every interest involved. Those two methods are: (a) mechanical separation and (b) engineering appraisal. Neither of these methods provides perfect allocation of the oil and gas in place, but they will gradually become more accurate as experience points the way. The United States Supreme Court recently observed that many questions arise in everyday business which cannot be answered with mathematical precision. Consequently, "the law, which is said not to require impossibilities, must be satisfied in many of its applications with fair and reasonable approximations⁸."

The *mechanical separation method* is based on uniform well spacing and uniform development and production methods. Under this condition the variations in potential capacity of the wells to produce are

⁸ Utah Power & Light Co. vs. Pfröst, 286 U.S. 165, at 191 (1932).

assumed to reflect the relative productivity of each tract. During periods of overproduction, when curtailment becomes necessary, the allowable is then prorated on the basis of potentials corrected by the scientific processes that are currently found to be applicable. Under this plan, the oil and gas produced from the wells on a tract are assumed to represent the oil that was in place on that tract. This assumption is false and inaccurate to a certain extent and is the same assumption on which the Capture Rule was originally based, but it is the nearest approach to recoverable acreage content that is applicable to nonunitized pools. The essential difference between this plan and the Capture Rule is that there would be complete uniformity of well spacing and development and production methods throughout the entire pool, and the aggrieved party would be entitled to compensation in damages, or a restraining order against the violator, whereas under the Capture Rule, as it had eventually developed prior to Proration, the owner of each tract was privileged to determine the well spacing and development and production methods for his own tract in total disregard of that which might be in general use throughout the pool, and the only remedy the aggrieved party had under the law was to drill offset wells and adopt other equally wasteful methods as did the violator.

There is a noticeable tendency under Proration to move from the unregulated Capture Rule toward this mechanical separation method of Ownership in Place, although the hangover effect of the Capture Rule still dominates oil and gas decisions and influences the granting of destructive exceptions to Proration rules. The Brown-Humble decision was based on a mild form of mechanical separation under Ownership in Place and was a distinct step in moving back toward the original intent of the Capture Rule as an incident in the administration of Ownership in Place.

The *engineering appraisal method* is based on estimates of recoverable acreage content developed from information on the reservoir and its contents, such as thickness and extent of producing sand, its porosity, permeability, and saturation; pressure in the reservoir; potential capacity of wells; and many other factors that must be weighed and evaluated in formulating estimates. In its application the respective owners are made tenants in common and share in all oil and gas taken at any point from the reservoir in proportion as the estimated recoverable content of each owner's land is to the estimated recoverable content of the reservoir. Under this method a period of planned exploration, including an exploratory drilling campaign, to define the pool and secure the necessary data on which to base estimates is essential before commercial exploitation is undertaken. It requires Unit Operation for its application.

As between these two methods of allocating oil and gas under Ownership in Place, the engineering appraisal method, if carefully done, is

most likely to approach nearer to exact justice. However, as previously stated, neither of them can distribute the oil and gas from the reservoir between owners on the basis of recoverable acreage content with mathematical accuracy, but they represent the nearest approach to that standard that it has been possible to devise. They come incomparably nearer to that ideal than the unregulated Capture Rule.

The engineering appraisal method, coupled with Unit Operation, is the only method of operation now known to students of the Industry under which it is possible to attain simultaneously both objectives set forth at the beginning of this paper. Furthermore, it is possible to do that with greatest degree of success only in virgin pools where the content has been undisturbed. Under those conditions appraisal engineers can determine relative acreage content by means of a preliminary exploratory drilling campaign with such reasonable dependability as will satisfy the standard set by the United States Supreme Court quoted above. Neither, as in "confusion of goods," will it be necessary to have actual identification of the oil and gas which migrated from one tract of land to another to establish ownership to that oil and gas, but justice is done and the law is satisfied by awarding the rightful owner an amount reasonably equal to that which migrated.

While the engineering appraisal method with Unit Operation would be the most efficient type of operation under Ownership in Place, it is essential to have as an alternative the mechanical separation method for those pools which for some reason are not susceptible to Unit Operation. With these two alternative methods it is entirely feasible for any State to discard the Capture Rule and operate wholly under Ownership in Place, except in those pools already wholly or partly drilled under the Capture Rule theory. Naturally, those pools should continue to exhaustion under the spacing they have already adopted.

Several years ago, after the American Petroleum Institute endorsed at Chicago under the title of "New Conception of Oil Development" the A.I.M.E. proposal of Ownership in Place, the engineers appointed by the American Petroleum Institute to develop a working hypothesis for the idea came to an impasse over the question of whether each owner was entitled to a quantity of oil and gas substantially equal to that which originally was in place, or whether, on the contrary, the assumed ability of properties higher on the structure to recover larger quantities of oil than those lower on the structure was to be given consideration. Influence against giving up that advantage of migration was sufficient to prevent its sacrifice. The argument was that this is a natural migration, and therefore the owner higher on the structure was entitled to that advantage.

The fallacy of that argument is that the movement up-structure is a natural movement only under the Capture Rule and would not be a natural movement under energy control. On the contrary, especially

in Unit Operation, the movement of oil more likely would be down-structure under the influence of an expanding gas cap. Full consideration of this question makes it clear that Ownership in Place should not include advantage of migration to "favorable" location on structure, for that would be merely continuing the Capture Rule with all its handicaps of waste and obstacles to securing cooperation. Each owner would agree only to that pattern of energy control that would drive oil toward his property. It might be more difficult to prevent that migration under the mechanical separation method of Allocation, but it would present no problem under Unit Operation.

Dissociated from the Capture Rule with a stabilized Industry, the allocation of markets would be much simplified and would find their solution with the restraint of trade practices.

Compulsory cooperation among adjacent owners is a simple, well-known procedure. For many centuries it has been a well recognized function of government throughout the civilized world to prescribe regulations for the better and more economical management of properties which adjoin, or for some other reason can be better managed or improved by joint operation. However, at this point it is pertinent to relate that Unit Operation has lost some of its original appeal as a corrective of the Oil Industry's ills because of dissatisfaction on the part of occasional participants at some fancied or actual lack of good faith on the part of those in whom operating control was placed. This differs in no respect from the experience of the average partner in any undertaking, the minority stockholder in any corporation, or the citizen of any government, yet we cannot discard either government or industry, nor should we discard Unit Operation as an objective, if it is mechanically sound. Needless to say, however, compulsory Unitization will not become popular, nor should it be attempted until processes of Unitization are evolved that will reasonably assure to the smallest minority participant justice and fair dealing in that relationship. Particular care should be taken to see that this applies with equal force to the smallest royalty owner as it does to the participating operator, for failure to Unitize the royalty interest presents the greatest mechanical obstacle to Unit Operation.

The *mechanical separation* method of allocating oil and gas under Ownership in Place would be less efficient in attaining both objectives than would *engineering appraisal*, but it is infinitely superior mechanically to the unregulated Capture Rule. And in any event it is merely a transition step in the change from the Capture Rule to actual Ownership in Place.

Ownership in Place will stand the mechanical test.

II. *Economic Advisability Test of the Capture Rule*

Waste and instability are difficult to estimate with accuracy. However, it is extremely probable that from the oil pools already exploited

at least one-half of the aggregate gas energy content was permitted to escape into the air without doing work, and one-half of the recoverable oil content was left unrecoverable in the reservoir due to reservoir energy dissipation. In addition to these results, needless duplication of facilities, instability in Industry, and many other uneconomic effects are directly traceable to the Capture Rule. Obviously, it is economically inadvisable.

The Economic Advisability Test of Ownership in Place

Self-preservation of the owner under Ownership in Place will induce him to correct without government compulsion the economic ills above described. It will be mechanically and legally possible for him to do so. Ownership in Place is therefore economically advisable.

III. Political Wisdom Test of the Capture Rule

The National defense, business structure, and social life of the Nation are all based on adequate oil supply. Its entire transportation system as now constructed is wholly dependent upon oil for its continued operation. Even those railways that do not use oil for motive power could not operate one hour without oil for lubricants. Developing adequate substitutes would require many years, radical changes, and vast expenditures of money.

On the other hand, the recoverable oil reserves from known fields within the United States have been currently reported by the United States Geological Survey, the American Petroleum Institute, and other reputable agencies at approximately 13 billion barrels⁹, which represents less than 15 years' supply at the present rate of consumption. The extent of the undiscovered reserves is unknown, but it is known that vast areas have been exhausted and that every process known to science is being utilized in the search for them; also that their possible quantity is dangerously limited in view of the extent to which the National life is dependent upon them.

These dangers are concealed and the nation is misled by the fact that the Capture Rule has promoted constant overproduction since the beginning of the Industry and created the impression that the supply of oil is inexhaustible. The total amount of oil produced in the United States since the beginning of the Industry represents only 20 years' supply at the present rate of consumption. The amount of oil involved in this constant overproduction status is insignificant in comparison with its psychological and economic result. If there is but a 30 years' supply and the Capture Rule forces its consumption in 25 years, there would be an embarrassing overproduction during that entire period, while at the same time the Nation could be facing early calamity due to oil shortage.

⁹ Congressman Samuel B. Pettengill in "Hot Oil," 13.

Thus, the United States, in the beginning of the oil age, faces early exhaustion of its supply, while competitive foreign Nations are only beginning to exploit theirs.

In view of these facts, the national political effect of the Capture Rule in promoting destruction of the nation's oil reserves and misleading the nation as to these dangers is beyond comprehension. It could easily lead the nation into a major national calamity. These are the immediate threatened consequences of the Capture Rule. In a broader political sense the Capture Rule is also politically unwise. Modern civilization and all its processes are built around a few simple principles, such as the right of the individual to life, liberty, and ownership of property. Anything that defeats or weakens these three concepts undermines the foundations of society.

Ownership of property to be beneficial must be fixed and certain. Uncertainty in ownership breeds either confusion or government control. The Capture Rule has that tendency. It is selfish, unsocial, and unmoral. It has been aptly termed legalized piracy. Its influence permeates every phase of the Oil Industry. It promotes waste. Nothing useful to society has borne that kind of ownership except things inexhaustible, like sunlight, air, and water, or nonessentials, like wild game. The wasteful disappearance of wild game till the government threw around it game laws is notorious. Game laws require government control in great detail. They are suitable for nonessentials, like wild game, but they are not suitable for exhaustible essentials on which great industries are founded.

Wasting oil and gas is politically unwise. Operating on a hand-to-mouth basis, rather than building up a dependable proven reserve, is politically unwise. Government by administrative fiat, rather than by specific law, where the latter is possible, is politically unwise. Absence of definite standards of value and conduct, by which citizens can plan their activities, rather than be forced to proceed on day to day changing bureaucratic instructions, is politically unwise. J. Howard Marshall, former member of the Petroleum Administrative Board, said before the Mineral Resource section of the American Bar Association (1935):

Both 'chaos' and 'prosperity' are still just around the corner for the Oil Industry, as they have been for a decade, and even in this program 'Federal control' is apparently expected to go to war with 'Interstate Compacts.' Such forensic warfare, however, between two competing catch phrases like 'Federal control' and 'Interstate Compacts' would most certainly fall far short of dealing with the stern realities of the present oil situation. . . . It is probably not a question of regulation or no regulation—it is a question of good or bad. Quite regardless of whether the East Texas field goes to salt water tomorrow or whether Kettleman Hills is destroyed by an earthquake, if the long predicted days of shortage return once more, that would only change the kind, not the existence of regulation. To those who believe that a shortage of crude would spell an end of all regulation, let it be noted that if it comes, the

probabilities point to its generating such political pressure by consumers as would undoubtedly force regulation in no uncertain terms. A little known and unheralded incident in the life of the Petroleum Administrative Board may serve to illustrate. When by some magical process the price of gasoline in the Island of Porto Rico rose to twenty-three cents a gallon a little over a year ago, it precipitated a consumers' strike which forced both the Petroleum Administrative Board and the Government of the Island to intervene to have the price reduced so that the streets might be cleared of tacks and other sharp-edged objects thrown for the purpose of paralyzing traffic on the island. We need not suppose that we are immune from forces which have compelled too stringent regulation of oil in other countries, and it behooves the Industry and its lawyers to properly gauge the tendency of the times and seek a form of regulatory program which will allow of a maximum efficient administration. . . . If it is a minimum of regulation that is desired, it would seem sensible to check the abuses that lead to the need of regulation.

Another politically objectionable result of the Capture Rule that has missed public notice is its tendency to promote destructive competition within the Industry and to place small operators and small companies at a disadvantage. The Capture Rule favors large company operation in many ways, but one illustration is that the instability of crude supply promoted by it requires vast transportation facilities to reach out constantly to remote new pools. The small refiner cannot afford to build such transportation facilities and consequently has no stable crude supply on which to build up his business over a period of years. Another example is the advantage the large oil company has over the small operator in its adequately staffed geological department under the Capture Rule that it would not have under Ownership in Place.

In all these many ways the Capture Rule is politically unwise. On the other hand, the Capture Rule is politically expedient at this time because of the mistaken conception that it favors the small man. When a true understanding of its influence in promoting large companies as contrasted with small companies becomes more general, it is probable that political wisdom and political expediency will go hand in hand.

The Capture Rule breeds destructive competition, and destructive competition in any industry inevitably weeds out the weak and leads to industrial monopoly or to government control. In the present state of public opinion, there is no danger of industrial monopoly's being permitted to exist, which leaves government control as the only possible result. Either monopoly or government control spells doom to free enterprise. From 1912 to the beginning of the Proration era the Oil Industry suffered all the throes of destructive competition. Under the Capture Rule Proration was a necessary evil. But it is also the first step toward government control unless the cause is removed. As failure follows failure under Proration in the attempt to accomplish what is mechanically impossible under the Capture Rule, more and more government control in the guise of relief will be demanded by both producer and consumer. Under the American conception of individual liberty it

is not the function of government to operate businesses but rather to establish conditions that will enable its citizens to do so, and to maintain justice and fair dealing between them, with a minimum of supervision and a maximum of freedom.

The Capture rule will not stand the political wisdom test.

The Political Wisdom Test of Ownership in Place

Ownership in Place represents a concept of property rights that is the product of centuries of experience among civilized nations. It stands for some fixed and definite amount, the quantity of which is ascertainable by engineering processes within margins of accuracy acceptable to the law. This concept of ownership is a simple one, readily understood by the least intelligent of men, notwithstanding he might not be able to perform the engineering processes involved in its determination. It has for its protection all the legal processes that have been built up throughout the centuries. It does not need government to fix the amount of oil and gas belonging to each owner. It needs government only to prevent violation of that ownership. The rules for its protection and enjoyment represent the wisdom of the centuries, as they have been worked out from experience for innumerable other kinds of private property, since the concept of ownership was first applied.

This type of ownership promotes saving and conservation, as contrasted with dissipation and destruction that arise out of the Capture Rule. It compels each owner to handle his own property so as not to violate the enjoyment of another owner. It promotes unselfishness and cooperation. It promotes stability and conservation. It lays the foundation for efficient recovery. It tends to protect the small operator against the large operator. It places them on a more nearly equal competitive footing. It protects the royalty owner against theft of his oil by others. It enables the Oil Industry to retain a maximum of self-government. It tends to perpetuate the nation's oil supply. It tends to prolong the time that the United States can compete favorably with other nations in national defense and in cheap transportation. All of these advantages are politically wise and will be politically expedient when their true significance is fully understood by the American people.

A friend to whom this paper was handed for criticism replied:

The enclosed discussion seems to answer successfully every objection which has been brought against the cause of Ownership in Place, save one. The matter of becoming vulnerable for further taxation has been talked about within the Industry, as you are no doubt aware. Some engineers feel that as soon as we definitely define the quantity of oil contained beneath a certain tract, the state legislatures would broaden the tax base to include it in the ad valorem assessment. I have heard it said that, with all the shortcomings of the existing Rule of Capture, it at least imposes no taxation until the oil is actually captured.

This point may have already been considered and brushed aside as inconsequential. It is not at all serious for the reason that we cannot turn our backs upon a progressive step for the negative purpose of outsmarting the tax collector. However, in a full discussion of the broad subject you might want to raise this objection for the simple purpose of answering it and thus disposing of it.

My friend is right. Exposing for additional taxation an Industry already carrying such a tax burden as the Oil Industry does is no inconsequential matter. I did not avoid it for that reason. However, the ostrich is generally considered a foolish bird. He might save his head by sticking it in the sand, but he only thereby exposes another portion of his anatomy to still more embarrassing indignities. So does the Oil Industry. No problem is solved by refusing to face facts frankly. Taxation is a legitimate and necessary function of government, but it is becoming onerous.

However, taxation problems cannot be solved by failing to lay all cards on the table and study them in a frank, open manner. Only by doing so can the Oil Industry establish that public confidence and cooperation so necessary to fair public treatment. It is an Industry vital to the public welfare. When the public is given all the facts and is assisted by the leaders of Industry in interpreting them honestly and fairly, then a constructive attitude may be expected on the part of the public's agent, the taxing authorities. If that is not true, then we must admit that democracy, as a theory of government, is a failure.

Considering all these facts, it is apparent that Ownership in Place will stand the political wisdom test proposed by Dean Pound but that considerable public misunderstanding must be corrected before it will be politically expedient.

IV. Legally Sound Test of the Capture Rule

Thorough consideration of the Capture Rule leaves no doubt but that it is mechanically impracticable, economically inadvisable, and politically unwise, although under the present state of public misunderstanding, it is politically expedient. Since the sole purpose of law is to promote the welfare of the people whom it governs, it follows that any Rule of Law which does not have that effect is fundamentally unsound.

The Constitution of the United States sets the legal pattern for this country. Its preamble reads:

We, the People of the United States, in order to form a more perfect union, establish justice, insure domestic tranquility, provide for the common defense, promote the general welfare, and secure the blessings of liberty to ourselves and our posterity, do ordain and establish this Constitution for the United States of America.

The Rule of Capture runs counter to every purpose set forth in that preamble. It promotes discord between the States, it works injustice between adjacent owners, it promotes destructive competition and

selfishness in the Industry as opposed to domestic tranquility, it destroys the most important item of national defense, it undermines the general welfare through waste and instability, and it denies the blessing of liberty to ourselves and our posterity through making necessary the substitution of government control for the free ply of private enterprise. It has been well described as legalized piracy, for it runs counter to every purpose for which government is established. It is a remarkable illustration of how the law in the mazes of its development can double back on itself and defeat its own ends. Considering all these facts, there can be little doubt but that the Rule of Capture is legally unsound.

The Legally Sound Test of Ownership in Place

Thorough consideration of Ownership in Place, as contrasted with the Rule of Capture, shows that it is mechanically feasible, economically advisable, and politically wise, although in the present state of public misunderstanding, it might not be politically expedient. An intensive study by leaders of public thought on the comparative tendencies of the Capture Rule and the Rule of Ownership in Place to promote monopoly would serve to change the political expediency status of these two rules. If that be accomplished, on the word of Dean Pound we should not have very much trouble in the end in inducing the courts of today to find that it is legally sound.

Certain other legal authorities have studied the question in detail and have written upon its legal soundness as follows:

Henry M. Bates, Dean of Michigan Law School, said¹⁰: (underscoring ours)

The adoption of these erroneous theories (analogy to wild game and percolating underground waters) has produced enormous losses and waste of valuable natural resources, which, though existing in abundant quantity, are nevertheless definitely exhaustible resources, vital perhaps to National defense in time of war and absolutely essential to industry, commerce, and transportation, as now conducted. The unrestricted exploitation of these natural resources set in motion a feverish and ruthless pursuit of this wealth in the ground that has lead to injustice among men scarcely less harmful than the great waste of these gifts of nature.

The abuses and evils in the production of oil, which leaders in the Industry itself are endeavoring to cure, are too well known to justify enlargement upon them here. The effect of early court decisions, based upon the erroneous theories heretofore referred to, was to make legal the pumping of all of the oil and gas possible from every man's well. Thus in the larger fields one producer might, and, in fact, often did, pump vast quantities of oil and gas underlying lands belonging to or controlled by other producers. This, in itself, violates any sane theory of property rights. It has induced a feverish scramble to get all that each owner can pump, regardless of whose land it underlies, and in order to prevent owners of adjacent lands from securing the oil lying therein. The mad scramble further resulted in the waste of vast quantities of gas which were allowed to escape in the air, a result not only disastrous in itself but

¹⁰ *Trans. A.I.M.E.* (1935) 114.

which produced even greater losses, in that the released gas was no longer available for propelling the oil toward the surface. The losses thus caused unquestionably mount into the billions of dollars and constitute the most reckless, extravagant waste of natural resources that even the American people have been guilty of. Moreover, this mad and greedy race for wealth has made it impossible in this country to adopt intelligent and effective methods of production, the cost of which has thus been made greatly and unnecessarily high. This high cost of production makes it impossible for American producers to compete with the British and other European producers owning oil rights in Persia, Turkey, and other countries.

Finally, those methods of production and distribution which have heretofore prevailed in this country have taken no account of the so-called economic laws of supply and demand, of present or of future needs, but have dumped upon an already saturated market vast quantities of petroleum, thus often depressing the market prices far below cost during this period of unintelligent and unjust distributive scramble.

The direction that remedial steps must take is fairly obvious, and several such plans have been outlined by the Industry itself and by others. It is unnecessary for me to describe here Proration and Unit Operation. The details of these and other suggested methods of production and of determining distributive shares are far better understood by members of this Institute than by me, but perhaps it may be pertinent to say that, from the lawyer's viewpoint, the most strongly supported proposals look to the establishment of certain corrective measures, among which are the following:

(1) the allotment to each producer of that proportion of the total oil and gas content of the field which lies beneath the land he owns or controls. We are told on good authority that as an engineering matter it is quite possible to ascertain with reasonable accuracy the share of oil to which each producer is justly entitled on this basis. (2) As the Proration plan in itself is inadequate to produce desired results for reasons well known, the idea of Unit Operation was developed and worked out in considerable detail. This aims not only at allocating to each producer his just share, but also it makes possible scientific and economic methods of production. Furthermore, Unit Operation would tend to secure production at times, places, and in the quantities reasonably calculated to adequately supply the market with prices just to the consumer as well as to the producer, and thus to conserve these great natural resources.

In an important case decided by the Supreme Court of the United States (Head vs. Mgg. Co., 113 U. S. 9) the court declared that 'when property in which several persons have a common interest cannot be fully and beneficially enjoyed in its existing condition that the law often provides a way in which they may compel one another to submit to measures necessary to secure its beneficial enjoyment, making equitable compensation to any whose control of, or interest in, the property is thereby modified.' The principle was recognized as long ago as the time of Lord Coke and is the basis of the numerous mill acts in New England, all of which compel the submission of individual rights to the common interests and rights of all concerned. Other examples may be taken from the maritime law and from the statutes relating to irrigation and drainage. In truth, the principle is well recognized and has been applied to many situations. In none of these older cases was the need of compulsory cooperation as obvious and as important as it is in relation to the production of oil. Not only is the necessity for compulsory cooperation greater and more demonstrable in the case of oil producers than in any other situations just referred to, but the public interest, both National and State, is infinitely greater.

"It is well known to all that the principle here contended for was essentially conceded in the case of Ohio Oil Company vs. Indiana, 177 U. S. 190. The Supreme Court in that case chose to base its decision principally upon the private interests of the owners and the necessity of doing justice among them. It might well, however,

have relied chiefly, if not exclusively, upon the importance of conservation to the public welfare and National needs. Reference will be made here to only one more case, that of *Marrs vs. The City of Oxford*, 32 Fed. (2) 134, in which the United States Circuit of Appeals, sustaining an ordinance of the City of Oxford in Kansas, set up at least a rudimentary scheme of compulsory Unit Operation. It is so clear that the just interests of all concerned would be conserved by the application of such a plan, and their ultimate profits increased thereby, that it seems reasonably certain that courts will sustain the application of the principle in proper cases, especially in view of the great stake which the public has in the matter.

Charles G. Haglund, in *Kentucky Law Journal*, May 1934, said:

An estate at common law extends vertically upwards and downwards. Each landowner over the pool is equitably entitled to all the oil beneath his surface confined within those vertical planes as it exists in the pool in its original state and before any drainage has taken place. If that oil content can be determined . . . then all the surface owners over the pool can be treated as tenants in common of the contents of the pool in the proportion that the oil underneath his surface bears to the total contents of the pool. It will then be immaterial through which well the oil comes or on whose land the well is located. Each tenant in common of the pool will receive his proportional fraction of the oil that comes from the pool irrespective of where the wells are located. If that can be determined, the pool can be developed as a unit along lines required to insure conservation and with justice to all the owners in the pool. That, however, presents an engineering problem which has not yet been fully solved However, an approximate determination of the acreage content with adjustments as new knowledge is acquired by drilling would afford greater justice to all than the present system of competitive drilling where those with facilities for handling production generally get far more than their share. Then the amount of oil that the pool would produce by conserving the gas pressure would be much greater than under competitive drilling, where it is wasted.

* * * * *

Certain legal principles which it is believed should be incorporated into the law of oil and gas have been worked out by lawyers and engineers, cooperating. The first principle clearly involves a determination of the acreage content before it can be administered. If this can be determined within reasonable bounds, not with mathematical accuracy, it should be sufficient. This determination, necessarily somewhat superficial at first, can be corrected and adjusted as development of the pool proceeds and new knowledge is acquired. Substantial justice to all is all that the law should require. Having achieved this, the law can declare the correlative rights of the various owners in the pool and make them tenants in common on the basis of such proportional determination of the contents of the pool. No Constitutional objection to enforced Unit Operation on that basis can be perceived. All owners will then be required to share in the expense of development and in the proceeds from the pool in proportion to their fractional interest in the pool as tenants in common. A compulsory development program must include a provision whereby owners in the pool, collectively, shall set up their own machinery for development and determine, collectively, the policies to be pursued in the pool.

W. P. Z. German, General Counsel for Skelly Oil Company, said¹¹:

Many years ago it was stated by the courts that the Government has the power to prescribe regulations for the better and more economical management of property of

¹¹ *Trans. A.I.M.E.* (1931) 92, Petr.

persons whose properties adjoin, or which, for some other reasons, can be better managed or improved by some joint operation. This early announcement was quoted by the United States Supreme Court in *Wurts vs. Hoagland*, 114 U.S. 606, 29 L. ed. 229. It was long ago held by courts, as is shown by quotations in the *Wurts* case, that where there are **ADJOINING LANDS HELD BY VARIOUS OWNERS IN SEVERALTY** and which, **BY REASON OF THE PECULIAR NATURAL CONDITION** of the whole tract, cannot be improved or enjoyed by any of them without the concurrence of all, there is presented a condition where the power of the legislature may be exerted to establish regulations whereby all may be compelled to submit to proceedings whereby they may be improved or enjoyed, and to contribute, in proportion to the benefits enjoyed by each, to the expense of the steps taken to accomplish such improvement or enjoyment.

Mr. German enlarged upon this idea at considerable length and showed that it has been widely applied for centuries in many lines of activity. He said:

This is a well known legislative power recognized and treated by all the courts and writers upon law throughout the civilized world: a branch of legislative power exercised both before and since the Revolution and before and since the adoption of the present Constitution.

Of course, it will be acknowledged by every honest engineer that the apportionment of oil and gas under Ownership in Place cannot be made with mathematical accuracy, but few things in life can be done on that basis. It is, after all, a case of relativity—not as between mathematical accuracy and the nearness with which engineers can approach it, but rather as between the results under the Capture Rule and the results engineers can achieve under an attempted apportionment on the basis of relative recoverable acreage content. Given a virgin oil and gas reservoir, petroleum engineers could certainly devise methods of apportioning its contents that would measure up to the standard of reliability specified by the United States Supreme Court. In fact, those who have made a study of reservoir conditions or engaged extensively in appraisal work know that can be done. Expressions by 17 nationally known American petroleum engineers on this point appear in the *TRANSACTIONS*¹².

RÉSUMÉ

Efficient extraction of oil and gas at the time and rate society needs them, together with equitable allocation of these products and the markets for them among their respective owners, are the two major objectives of the Petroleum Industry. Stability within the Industry is dependent upon accomplishing both of these objectives. However, simultaneous accomplishment of both objectives under the Capture Rule is impossible. It is, therefore, mechanically impracticable. It promotes high cost, waste, and inefficient recovery to a degree that

¹² *Trans. A.I.M.E.* (1932) 98, 31-37.

compels the granting of subsidy through tariff protection to keep the Industry solvent. It is therefore economically inadvisable. It weakens national defense, promotes discord between states, imposes burdensome administrative duties upon government, dissipates the nation's natural resources, induces high cost of living, endangers the nation's transportation system, and weakens its ability to compete with other nations in war and in peace. It is therefore politically unwise, although it is at this time politically expedient because of public misunderstanding. It runs counter to every purpose for which law is established. Therefore, it is legally unsound. For these many reasons the Rule of Capture cannot be rationalized. It is inherently in conflict with the functions of government, and the higher impulses of mankind. It is a destructive influence.

On the other hand, Ownership in Place is the direct antithesis of the Capture Rule in every respect mentioned. It tends to build up, while the Capture Rule tends to tear down. It has for its orderly administration every process of ownership devised through the centuries. In its application two methods of allocating the product among owners are available, namely, the mechanical separation method in non-unitized pools and the engineering appraisal method in unitized pools. Neither method would be mathematically accurate, but both can be made to do substantial justice among owners and come within standards set by the Law. Both are incomparably better than the Capture Rule to attain that end.

Under the American conception of individual liberty, it is the business of government to establish rules of action designed to promote free enterprise, justice and fair dealing that will operate with a minimum of supervision and a maximum of freedom. The Capture Rule and Ownership in Place represent two distinct concepts of ownership. One breeds government regulation. The other breeds industrial self-control.

The Capture Rule not only compels withdrawals from the reservoir at improper points, thus dissipating reservoir energy without utilizing it in oil recovery, but it places upon government the impossible policing task of preventing the inevitable result of that mechanical method. Government bureaus multiply when government pursues will-o'-the-wisps. Failure merely promotes renewed efforts, for the public pays the bills, which soon places government in business. We may concede government bureaus the legal right to do the impossible thing, but we cannot clothe them with the ability to do it. On the other hand, Ownership in Place not only opens the way for mechanically accomplishing the desired objective, but it supplies processes centuries old, under which wronged owners can protect themselves from the violator and thus induce the necessary cooperation that will promote free enterprise, justice, and fair dealing with a minimum of supervision and a maximum

of freedom. Progress toward individual freedom is not made by imposing impossible tasks upon government bureaus.

In like manner as Ownership in Place is the antithesis of the Capture Rule so are the results of Ownership in Place the antitheses of results that arise out of the Capture Rule. It accomplishes nothing to concede the State legal authority to regulate the Capture Rule with a view to accomplishing certain results, provided regulating the Capture Rule to that end is physically impossible. Government employees are human beings, subject to human limitations and human frailties.

The Capture Rule breeds destructive competition, and destructive competition leads either to industrial monopoly or to government control. Since industrial monopoly would not be tolerated in the present state of public opinion, the inevitable result must be government control, if that rule is perpetuated. The Oil Industry is now in the process of passing out of the stage of destructive competition into that of government control, a thing we need to avoid equally as we do industrial monopoly. The Oil Industry can avoid both. It is the function of this symposium to consider means to that end.

Governmental Regulation of Oil Production

BY NORTHCUTT ELY*

(New York Meeting, February, 1937)

THE subject of this paper implies three questions: whether regulation is necessary; if so, what sort of regulation is wise; and, finally, by what government the power to regulate is to be exercised.

In the year 1937 emphasis falls on the third of those questions. This contrasts with the situation prevailing a dozen years ago, when the question was whether regulation was necessary at all; and with the situation a few months ago, when the third question seemed answered by the Supreme Court decisions on the National Recovery Act, Agricultural Adjustment Act and Guffey Coal Control Act, and by the ratification of the Interstate Oil Compact. It then appeared settled that the State and not the Federal Government possessed the regulatory powers and, granting that conservation measures are a recognized necessity, the problem seemed to be to develop the wisest kind of regulation that the Constitution would permit. Today, by virtue of developments during the first months of 1937, the oil industry is faced again by the question of whether the Federal Government is to have power to control its operations, along with those of the other basic industries.

DEVELOPMENTS IN GOVERNMENTAL CONTROL

There have been three recent developments. The dominating one is the President's proposal that he be authorized to increase the size of the Supreme Court to 15 members. The implications of that plan ought to be perfectly plain to the oil industry. This suggestion is made in lieu of offering an amendment to the Constitution, to reverse the Supreme Court decisions mentioned. In those decisions the Court held that production does not constitute commerce, and hence that the Federal power to regulate interstate commerce does not extend to the regulation of production. These holdings were contrary to the Government's contention that the stream of commerce begins in the factory and ends with the consumer and may be regulated at any point from beginning to end. That position was urged in the Government briefs in *Amazon Petroleum Co. v. Ryan*, defending the petroleum code, and repeated as late as Feb. 10, 1937, in the case of *National Labor Relations*

Manuscript received at the office of the Institute Feb. 18, 1937.

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Board v. Jones and Laughlin Steel Corp. (No. 419). If this doctrine, so recently rejected, is to be accepted by a new court, the oil business is squarely in the line of march. This industry gathers oil from about 350,000 wells, runs it through a few hundred refineries, and out again, in refined form, to about as many service outlets as there are wells, and thence to more than 26 million consumers. In the process, it furnishes the major part of the horsepower for all prime movers. The mileage of its pipe lines, traversing 24 states, is a third that of the major railroads. Interference with gas production going into an interstate pipe-line system has been held by the Supreme Court to be interference with interstate commerce. If the commerce power is to be the raft on which new Federal industrial legislation is to float to safety, it is difficult to conceive of a decision validating Federal control of crop production, or Federal control of wages in a coal mine, which does not automatically validate Federal control of oil production. This is particularly true because here the stage at which regulation is applied can be chosen so as to focus attention on the pipe line rather than on the oil field.

The President has also transmitted to Congress a plan for reorganization of the executive departments, wherein he proposed to rename the Department of the Interior "the Department of Conservation." This is a day of National Resources Boards, National Planning Committees, World Power Conferences, and interest in all natural resources. The authority delegated to deal with oil would probably be thorough and the depository the Department of Conservation. There the oil industry would find the coal business and some phases of the power business already installed as neighbors.

The third development is the Supreme Court decision in *Thompson v. Consolidated Gas Utilities Co.* on Feb. 1, 1937, striking down the Texas statute under which ratable taking had been ordered by the Railroad Commission in the Panhandle gas field. This is the first Supreme Court decision wholly adverse to a state oil or gas conservation statute since 1922. For reasons to be referred to later, the *Consolidated Gas* decision has many helpful points in it. But, coming in this series of events, it points up a fundamental question: Does the present system of oil conservation laws, operating primarily through the police power of the states, supplemented by valuable but incidental Federal activities, and supplemented by the Interstate Oil Compact, have intrinsic merit enough to stand up against a drive for general Federal regulation of industrial production? This serious question requires an objective examination of the present technique of oil conservation.

LEGAL MECHANISM FOR OIL CONSERVATION

The present legal mechanism for oil conservation is well recognized. At the base is the police power of the state, specifically the dual power

to prevent waste and to protect the correlative rights of common owners. This power is exerted by statutes delegating authority to regulatory boards, generally the same bodies that regulate public utilities. Oil production has not been held to be a public utility, but the powers exercised over production are very broad, including control over spacing of wells, manner of drilling, proration of a field's production (determined either by market demand or waste consideration), control of gas-oil ratios, and transportation. Superimposed at this stage are three other agencies: first, the Federal Connally Act, whereby oil produced in excess of production allowed by the state is denied access to interstate commerce; second, the Interstate Oil Conservation Compact, under which the state regulatory bodies coordinate their activities through a joint commission; and, third, the Federal Bureau of Mines, which forecasts demand and recommends to the states the volume of oil they should produce. Alongside this structure is the independent Federal control over imports, through an excise tax.

This mechanism was evolved during the decade between 1926 and 1936. It is a product of an era wherein, generally speaking, inventories were increasing below ground as well as above. It has been operated as an engine in reverse gear, to hold back excessive potential production built up by excessive drilling, which in turn was occasioned largely by the operation of the "rule of capture." It is interesting to note that in its two essentials, that is, determination of demand by the Federal Government and corresponding adjustment of supply by the state governments, this process does not differ greatly from actual practice under the petroleum code. Its origin was in the first report of the Federal Oil Conservation Board, in 1926, and it was amplified in the Board's fifth report, in 1932, and discussed in several professional papers.

The weaknesses of this system lie in two phases, both of which the Federal Oil Conservation Board diagnosed, and for which it proposed remedies which as yet are only imperfectly adopted.

State Statutes Imperfectly Correct Abuses

First, the state statutes do not fully occupy the ground constitutionally open to them. They imperfectly correct the abuses of the rule of capture; they cause more litigation by their tenderness toward this obsolescent rule of the common law than would result from strictly controlling it. For example, the Texas statutes authorize the Railroad Commission to enforce spacing of wells, and to enforce proration of production. But they have specifically prohibited the compulsory unitization of properties. The results? Not less than seventy decisions on the spacing rule have been reported in less than four years, arising from the dilemma thus forced on the Commission when confronted by

competitive drilling on tracts of small acreage. Most of these are cases in which the Commission granted exceptions to the spacing rule, whereupon adjoining landowners appealed to the courts; and generally the rule was sustained and the exception struck down. Of 23,000 wells in East Texas, 16,000 have been drilled under exceptions to the spacing rule. Allowables per well have been reduced to correspond with the increase in number of wells, so that over 97 per cent of the current production from East Texas is allocated as though produced by marginal wells—that is, a flat allowable of a few barrels daily is made to each well. But the Commission has met a series of Federal decisions striking down every order restricting production save that setting up this system. In the Panhandle field, twelve reported decisions and two unreported ones have invalidated every order compelling ratable taking of gas by the pipe lines, and have sustained only the orders prohibiting use of sweet gas for carbon black and for gasoline stripping operations. The latest decision is that of the Supreme Court in the *Consolidated Gas* case, already cited. This decision adopted findings of fact made by the trial court, to the effect that drainage was away from wells connected with the plaintiff's pipe lines and toward the wells of others, operated for carbon-black manufacture. On that finding, the Supreme Court held unconstitutional a statute which it construed as requiring the pipe lines to curtail their takings from their own wells regardless of the direction of drainage. In so doing, the court made two significant points: it reaffirmed the rule of capture as the common law of Texas, but specifically restated the state's power to modify that rule by legislation based either on prevention of waste or on the adjustment of correlative rights. It invalidated the law in question because, as a matter of fact, the pipe-line wells were not disturbing the pressure in the areas of the unconnected wells, and the mischief was being done by the carbon-black wells. The lower court had refused to concede that the Supreme Court decisions in the cases of *Bandini Petroleum Co. v. Superior Court*, *Champlin v. Corporation Commission*, *Ohio Oil Co. v. Indiana*, and *Walls v. Midland Carbon Co.* had rested on the power to adjust correlative rights, independently of waste. The Supreme Court's reassurance on that point indicates the domain open to future legislation, and that is more important than the fate of the particular Texas legislation struck down.

The situation in Texas has been emphasized here because that state now produces two-fifths of the oil and a greater share of the oil litigation. But, painful though the progress of the conservation laws has been in Texas, compare it with that in California, which has declined to control production at all, save through a gas-waste statute, and Michigan, where, despite the enactment of a fairly good statute, 40 per cent of the state's then known reserves were produced in a single year.

States Refuse Recommendations of Bureau of Mines

The second basic weakness in the present system is the failure of the states, in their compact, to commit themselves to abide by the Bureau of Mines' production recommendations. This reluctance had its origin in the belief that the laws of Texas would not countenance recognition of market demand as a limitation on production, and in distrust of Federal dominance of the compact. Both objections are dubious as a matter of law, if not of politics. The Texas statutes now recognize that production in excess of market demand is waste; and the Supreme Court's Consolidated Gas decision assumes that such provisions are valid. As to Federal dominance, the Bureau of Mines has no coercive powers, but is a highly scientific fact-finding agency. It is better to cooperate with that kind of an agency than to provoke the establishment of one of a different type.

For comparison, the plan proposed by the Federal Oil Conservation Board reads as follows:

- (1) The creation of a joint Federal and State fact-finding body to forecast demand, recommend crude-oil production, and allocate it among producing States and imports.
- (2) A commitment by each producing State to adhere to its quota.
- (3) Federal regulation of imports to keep them within the prescribed quota.
- (4) Formulation by this interstate body of uniform conservation principles for adoption in local legislation centering around unit operation and the preservation of reservoir energy.

The Compact is not as yet accomplishing in full its great opportunity for the development of model conservation laws, research on conservation methods, cooperation in checking tax evasion, and other useful work, in addition to the fundamental job of coordinating the activities of the public service commissions. But the important fact is that the compact exists, and that it is a constitutional successor to a method held unconstitutional by the present Court.

EFFECTIVE MECHANISM

Conceding that the conservation tools are not as sharp as the states could make them, and that their use is not fully coordinated, the question is whether it is better to improve these tools or set up a new machine.

We have said that the first weakness of the present system is its ineffective regulation of the law of capture. But it should not be assumed that the Federal Government could strike the root of this evil any harder than the states can hit it, even if the commerce power were interpreted to clothe the Federal Government with the full equivalent of the state's police power. Every statute controlling a man's use of his own property,

whether it is a Federal or a state statute, must clear two constitutional hurdles: First, is there power in the legislature to act? Second, if the power exists, is it being so exercised as to deprive a man of his property without due process of law? The Federal Government is subject to the due process clause of the fifth amendment, just as the state is subject to that of the fourteenth. Equipping the Federal Government with power equal to the police power of the state would not lift the barrier to the exercise of that authority raised by the due process requirement. The *Consolidated Gas* case is an example. What halted the Texas statute there was not the lack of power to adjust correlative rights, which was sustained, but the fact that this authority, exercised as this statute sought to exercise it, expropriated the pipe line's property without compensation and for a private use. The Federal Government, had it possessed a similar power, would have encountered a similar prohibition against its exercise on the facts of that case. A new interpretation of the commerce clause, while it might help to keep Federal oil-control laws on the statute books, would not alone make those laws effective against the due process clause.

The remedy seems to lie not in a change of venue, but in a change of policy. There will never be a wholly effective conservation statute until the lawmakers recognize that an oil field is physically one unit and must be treated as one by the law. Ray Lyman Wilbur, when Secretary of the Interior, said, "There are two ways in which to settle disputes over an oil field: One is by conference around a table on the surface, and the other is a mile underground with the drill." The common law adopted the more primitive method. The engineers teach us that an oil reservoir is an engine by means of which natural forces lift oil to the surface, if properly controlled. The common law treats the engine as though it were on a scrap heap to be dismembered and carried away for the value of its metal by the first takers. Attempts at spacing regulations and at proration of production based on "potential" or on the number of wells are simply palliatives. The defect of the statutes is the failure to make the pattern of drilling conform to underground characteristics of the pool instead of surface fence lines. The trouble begins with the drill and much of it can be ended there. Oil does not become fugitive until drilling of the first well disturbs the natural balance of forces, and the way to correct a doctrine based on the fugacious character of oil is to control the opportunity to disturb that natural balance. One such control might be a statute requiring the development of new fields by operating districts modeled on those sustained in *Marrs v. City of Oxford*. If such a statute were conditioned on findings of probable "undue drainage" between districts, in deference to the *Consolidated Gas* decision, the regulatory body could probably fix drilling ratios as well as production ratios as between districts, apportion production between districts instead of

leases, and allot each district's allowance among all of its leases as was done in the *City of Oxford* case. The draft of such a statute for "unitary allocation" was published by the writer in 1933, and recent New Mexico and Oklahoma statutes tend in the same direction. Federal legislation is not necessary to such a reform. But compulsory unit operation is enforced in new pools on the public domain under Secretary Wilbur's regulations of April 4, 1932; it was attempted in new private fields under the petroleum code; and if Federal control returns to judicial favor compulsory unit operation will be a likely feature of it.

Turning to the second of the Federal control features: It is not clear that displacement of the compact by a Federal regulatory commission would create more than it would destroy. Three parts of the present machinery would probably be preserved in any event: the control over imports, the Connally Hot Oil Act, and the fact-finding services of the Bureau of Mines. These are proper functions of the Federal Government. But if the principle of dual sovereignties is to survive in our governmental system, it seems wise to use the full capacity for public service that each government possesses. The state's powers are constitutionally fitted for the regulation of production. The compact clause is the Constitution's method for gearing that force to a regional problem. This has long been recognized in other fields, and the oil compact has prompted proposals for similar control of other commodities, particularly tobacco, coal and milk.

The oil compact itself is new, and, as time goes on, it may more closely approximate the specifications of the Federal Oil Conservation Board, and the later suggestions of Governor Marland. However unfinished the present compact may be, this agreement is a start along the only constitutional course that has yet been charted. If, after use, it fails to develop constructively, then proper Federal powers can supplement it. For instance, there are arguments for greater participation in the Compact Commission by Federal representatives. Some compacting states would welcome that development. But the changes, if any, ought to be in the direction of greater cooperation between the Federal and state governments, not the aggrandizement of one at the expense of the other.

The current is running toward a centralized government, whether or not the move to reorganize the Supreme Court succeeds, and the oil compact must be made seaworthy if it is to move against that current and to set a course for other industries to follow through the sea of governmental relations.

FORCES WORKING TOWARD CHANGE

We have tried to appraise the good and bad features of the present system. In closing, let us measure the forces which are working toward a change.

The oil business may profit by examining the experiences of two other energy-producing industries, electric power and coal. There are family resemblances in some statistics of these natural resources. Oil and electricity (including steam-generated power) each claims an investment of about thirteen billion dollars, and about twenty-six million ultimate consumers. Both have steadily reduced the prices of their products. As to oil and coal, the investments are not greatly different and the annual energy output of the two is roughly of the same magnitude. During a time when oil was acquiring its unique control mechanism, meanwhile keeping free of a public utility status, these sister industries were becoming securely stuck in the Federal flypaper. As to electric power, the record is familiar: the Federal Water Power Act, the Holding Company Act, Boulder Dam, Bonneville, Grand Coulee and Tennessee Valley projects, subsidies for municipal plants, and so on. As to coal, the Guffey Coal Control Act is fresh in mind.

If public opinion has been thus aroused to conserve water power, which is annually replenished, and coal, of which we have many hundred years' supply, it is apparent what a fruitful field is presented by the oil industry. Here we have in sight reserves for but ten to fifteen years and we have left underground, most of it lost forever, a great deal more oil than has been taken out. Whenever the price of gasoline, loaded with gasoline taxes, begins to crowd the consumer and he turns the issue of conservation into an emotional one, it will do little good to give him reasons why the country's oil has been wasted, even though the oil industry believes that the reasons are good ones. Whoever reads the papers on oil, coal and electric power submitted at the 1936 World Power Conference can imagine a similarity in the handwriting on three different walls.

The suggestions repeated in this paper, for strengthening the state conservation laws in the direction of drilling control and compulsory unit operation and re-enforcing the Interstate Compact in the direction of a firmer agreement, are probably no more attractive politically now than they were when the Federal Oil Conservation Board first made them. But it may be more acceptable in the long run to strengthen the present conservation structure from within than to wait for others to pull it down from the outside, and move it to a new location on the other side of the Constitution. The foundations under the new location look none too safe, and the architect's drawings are not very reassuring as to the uses for which the structure might be adapted.

Economics and Well Spacing in Texas

BY WILLIAM E. HUBBARD,* MEMBER A.I.M.E.

(Fort Worth Meeting, October, 1936)

DURING the last decade the known reserves of petroleum in the United States have increased from about five billion to over thirteen billion barrels. From the standpoint of public welfare the existence of these known reserves presents an undeniably favorable picture, but viewed from the position of many a harassed operator the blessing has not always been considered an unmixed one.

Along with this increase in excess reserves, curtailment of production has come into being as a matter of necessity and the principle of proration as a matter of equity. As a practical matter it has been considered necessary to curtail the production of old wells as well as that of new wells in a pool. The right of new pools to produce has been recognized, and the allowable for them has come partly from increased market demand and largely from the allowables already enjoyed by the developed pools. The natural result—a downward trend in daily per-well allowables—has

TABLE 1.—*Trend in Five Active Areas in Texas^a*

Year	Average Number Wells	Total Daily Allowable, Bbl.	Daily Allowable per Well, Bbl.	Daily Allowable Rest of State, Bbl.	Total Daily State Allowable, Bbl.
1933	16,418	706,500	53.8	393,500	1,100,000
1934	20,041	733,500	37.7	302,500	1,036,000
1935	25,224	808,500	32.2	263,500	1,072,000
9/1/36	34,973	890,500	25.4	238,500	1,129,000

^a Gulf Coast, East Texas, West Texas and districts 2 and 4 of Southwest Texas.

been especially felt by Texas operators. This trend may be illustrated by Table 1, which comprises the five active areas in Texas, and from which may be noted the following:

1. The average daily allowable per well has decreased about 53 per cent in three years.

2. Of the 184,000-bbl. increase in total allowable for the five areas, 29,000 bbl. came from the increase in state demand and 165,000 from the combined allowables of the remaining pools in the state.

Manuscript received at the office of the Institute Oct. 8, 1936.

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As of June 1, 1936, there were 21,080 wells in the state that had allowables greater than the marginal allowable for their respective depths. That part of their allowable over the marginal totaled 348,700 bbl., or a sufficient surplus to furnish marginal allowables for about 17,500 new wells. Since that time over 3000 additional producers have been completed. There is apparent justification for the widespread belief that practically all Texas wells will be down to their marginal allowable in a very few years unless the rate of drilling materially decreases.

For several years the principle has been recognized that oil can be recovered without waste by wells spaced more widely apart than was the former custom, especially under conditions of restricted production. Of the 69 Texas pools for which special field rules have been promulgated, 88 per cent have spacing rules of 10 acres or more per well and 33 per cent have rules of 20 acres or more per well. Pools having spacing rules of 10 acres or more comprise 242,000 developed acres and 29,000 wells. Pools for which orders have been issued devoid of spacing rules, but which, nevertheless, have 10-acre spacing by operators' preference, comprise 17,000 acres and 5,700 wells. The present allowable of these pools is 852,700 bbl., or 24.6 bbl. per well. Were they drilled to a 4-acre density—that of the average Balcones fault line pool and more or less typical of Mid-Continent practice during the early twenties—their average allowable per well would be 13.3 barrels.

This trend of the last several years toward wider spacing has served to delay if not to avert a demoralized condition in the industry.

A critical point has been reached, however, wherein the production of each new well adversely affects the allowable of wells already completed. Mounting unit costs follow decreasing allowables, and the margin of profit, never large on the average, continues to shrink. The pay-out period of a well, formerly days or weeks, is now measured in years. The completion of 20,000 wells annually in the United States means a drilling cost of close to one-half billion dollars, or about fifty cents per barrel produced. The producing branch of the industry is credited with an investment of about $5\frac{1}{2}$ billion dollars. With crude at a dollar per barrel the rate of return on investment can be estimated at any figure from 3 per cent down.

In 1934, for the State of Texas, the costs per gross barrel produced, figured on a cash—as opposed to a profit and loss—basis, were approximately as shown in Table 2. A few items, such as geological work, land and engineering expense, and cancellation and amortization of undeveloped leases, are not included in this tabulation because all operators are not directly affected by them.

The importance of the total item for drilling (47.6¢) becomes obvious, especially as it is the only item that can be materially reduced in any attempt to decrease costs. However, 1936 costs are higher than those

shown, for the number of wells drilled is about 23 per cent greater, indicating a drilling cost of 51.7¢ per barrel produced.

TABLE 2.—*Costs in State of Texas in 1934*

		COST PER GROSS BARREL
Drilling:		
Oil wells.....		\$0.382
Dry holes.....		0.094
Operating.....		0.164
Royalty.....		0.156
Bonuses and rentals.....		0.157
Salaries and office expense.....		0.052
Total.....		\$1.005

An analysis of the future period of time during which the capacity to produce will be in excess of the demand has economic importance but presents difficulty. An inference may be drawn by considering the 12 major pools in Texas that have an estimated recoverable reserve of over 50 million barrels each.

These pools have reserves of about 4.7 billion barrels, 25,000 wells and about one-half of the state allowable production. The average density of drilling is now one well to 9.55 acres and will be one well to 8.32 acres when the pools not fully developed are drilled down to their respective spacing rules.

TABLE 3.—*Decline and Production*

Time	Total Potential, Bbl. × 1,000,000	Potential per Well, Bbl.	Cumulative Production, Bbl.	
			× 1,000,000	Percentage of Ultimate.
0.....	380.0	13,250	0	0
1 day.....	30.0	1,045	40.0	0.85
5 days.....	21.3	745	129.5	2.76
10 days.....	15.0	523	213.0	4.53
1 month.....	9.0	314	426.0	9.07
2 months.....	7.3	255	663.0	14.12
4 months.....	5.6	195	1,041.0	22.20
6 months.....	4.7	164	1,339.0	28.45
8 months.....	3.1	108	1,555.0	33.10
1 year.....	2.25	90	1,877.0	39.90
2 years.....	1.5	60	2,557.0	54.30
3 years.....	1.0	40	3,012.0	63.00
4 years.....	0.75	30	3,332.0	70.78
5 years.....	0.60	24	3,578.0	76.05
6 years.....	0.45	18	3,769.0	80.21

Based upon productivity indices and known open-flow data in a few of the pools, the total open-flow potential may be estimated at 380 million barrels, or slightly over 13,000 bbl. per well. As the initial production of the first wells at Powell was of this approximate magnitude, and as detailed decline data for Powell are also available, an assumed curve was reconstructed from the Powell curve to reflect what changes would have occurred had all of the wells started producing at capacity simultaneously and had the density been 8.32 acres per well. Decline and cumulative production data from this curve are given in Table 3. The table would indicate the following:

1. Present potentials are meaningless and under open flow could not be approximately maintained for more than a matter of minutes or seconds.
2. Under open flow the combined potential of the 12 pools would be down to 3.1 million barrels, or the present national demand, within eight months.
3. If produced at the national daily rate of production, they could probably maintain that rate for 500 days.
4. They could probably produce the present total Texas allowable for a period of 6.68 years.
5. By projection, the curve would indicate that at 5.13 years the potential would be equal to the present rate of production, or 580,000 bbl. daily. At such time 3.58 billion barrels would have been produced, indicating that, with the production held at the present rate, 16.9 years would elapse until wide open conditions would prevail.

A second method for arriving at a quantitative result is the following: In 1925 the Committee of Eleven estimated our United States reserves at 5.3 billion barrels. In 1926 the Federal Oil Conservation Board estimated them at 4.5 billions, an average for the two-year period of 4.9 billions. In 1925 twenty-six million barrels were added to stocks and in 1926 twenty million barrels were withdrawn. The average yearly production for the two years was 767 million barrels.

Assuming that for the two-year period there was an approximate balance between demand and wide open production, the factor of $4.9 \div 0.767$, or 6.385, becomes significant. The factor merely means that if the existing rate of production could have been maintained, the supply would have lasted for 6.385 years or that there would have been 6.385×365 , or 2330 bbl. back of each barrel of daily production.

On this basis, the number of years that will elapse before potential and demand are in balance may be derived from the following equation:

$$\frac{R + nF - n\left(P + P\frac{r(n+1)}{2}\right)}{P(1+rn)} = 6.385$$

Where R = present reserves,
 n = number of years,
 p = present yearly demand,
 F = yearly finding of new reserves,
 r = average rate of increase in yearly demand over 1936.
 (All barrels in billions.)

TABLE 4.—*Elapsed Years*

Yearly Finding, Bbl. $\times$ 1,000,000	0	250	500	750	1000
Increase, Yearly Demand, Per Cent					
0	5.80	7.58	10.91	19.51	92.3
2½	5.11	6.27	7.91	10.74	15.01
5	4.26	4.70	5.63	7.08	9.10

Table 4 is derived from the equation and assumes that cracking efficiency will remain constant. Neither of the extremes presented in the table is claimed to be reasonable. The important point is that proration is inevitable for a period of many years. The period will probably be extended by the necessity for maintaining an excess of reserves over demand for the emergency of war. Drastic changes in motor design and hydrogenation are already waiting their turn as conservation agents. Sound predictions have been made that crude-oil requirements for 1960 will be below those of 1940. It might not be unreasonable to assume that some measure of restriction upon open flow may be employed indefinitely.

The most important factors affecting the price of crude today are supply and proration. The elements of supply may be grouped as follows:

I. Underground reserves

A. Unproved

B. Proved

C. Developed

1. Rate at which producible or well density

II. Aboveground reserves

Unproven reserves have no effect on price. Likewise proven reserves, if scantily developed, have little if any effect on price. Developed reserves have a varying effect depending on the intensity of their development, for it is the surplus capacity to produce reserves and not reserves themselves that presents an ever-present threat to market stability. The drilling of wells over the amount necessary to satisfy the market demand without waste has a dual effect as a natural price depressant, for reserves are not only made more immediately available to the market thereby but the lower allowable per well decreases the margin of profit,

and, by thus increasing the amount of distress oil, increases the urge to overproduce.

Aboveground reserves, ignoring seasonal variations, have become a barometer of the effectiveness of proration control, and as such have probably as much influence on price as in the past.

Proration has had a natural effect of stabilizing price at a level somewhat above that which would be determined by the free operation of supply and demand. This is because excessive aboveground storage is considered conducive to physical waste, and it therefore follows that one of the functions of proration is the limiting of production to market demand. However, any attempt to control price further than this by proration would meet with disaster. If allowable production exceeds demand materially, prices drop, and any attempt to raise prices by prorating to a point below market demand would make such proration order vulnerable to court attack.

Likewise any attempt by anyone to arbitrarily raise prices would invite the drilling of additional unnecessary wells and merely aggravate the prevailing tendency toward instability. Demand itself can be stimulated only through price recessions or the offering of a higher grade product.

Regulatory bodies, charged with the duty of securing allowable production for new wells, are faced with a task increasingly difficult. The majority in the industry is agreed that there are too many wells and that too many are constantly being drilled. Both the cause of and the answer to the problem are fairly obvious. Table 5 is indicative of the cause. It purports to show the relative amounts that properties with

TABLE 5.—*Ultimate Production per Acre Based upon Method of Proration*

Size of Tract	Production per Acre, Bbl.			
	Oil in Place	Cutler Theory	A + P	100 Per Cent P
10 acres.....	10,000	10,000	10,000	10,000
5 acres.....	10,000	14,100	15,000	20,000
2½ acres.....	10,000	20,000	25,000	40,000
1¼ acres.....	10,000	28,200	45,000	80,000
⅝ acres.....	10,000	40,000	85,000	160,000

equivalent well potentials would be allowed to produce under different conditions of proration and well density. A spacing rule of 10 acres and the presence of 10,000 bbl. per acre of recoverable oil are assumed. The table shows the following:

1. With strict enforcement of spacing rules devoid of exceptions, each lease receives its proportional part of the oil in place under any of the four proration methods shown.

2. In the drilling of various sized tracts, both equity and the drilling of a minimum number of unnecessary wells may be achieved by proration on an oil-in-place basis.

3. Proration based on the Cutler theory furnishes a substantial incentive for close drilling. (This theory has been advanced by supporters of close spacing as a measure of the condition existing under the operation of the rule of capture. Strangely enough, it has never been used in a proration formula.)

4. Neither $A + P$ nor 100 per cent P prorate either on the basis of the rule of capture or oil in place, nor are they compromises of the two.

5. Potential, as currently used, is no measure whatever either of oil in place or of expected recovery under the rule of capture.

6. Existing proration methods have given an arbitrary value to small tracts out of all proportion to their intrinsic worth. Whatever may be the group that this system is designed to assist, it is unsound, for competitive bidding will eventually raise the purchase price of such tracts to a level commensurate with the return on investment.

SUMMARY AND CONCLUSIONS

1. Per-well allowables in Texas have dropped at a rapid rate during the past three years. It appears that no well can be allotted more than the marginal allowable for its depth within a comparatively short time.

2. The presence of large excess reserves indicates that sharply curtailed production will be inevitable for many years.

3. A certain amount of wide spacing has served to avert a chaotic condition, but too many wells have been drilled and a critical point has been reached.

4. For the producing industry to be established on a sound and profitable basis a drastic decrease in rate of drilling is necessary.

5. Excess reserves are of such magnitude and the rate at which they can be produced is so great that price stability is constantly threatened and is maintained only by proration.

6. A legitimate function of proration is the limiting of production to market demand, but any attempt to control price by exceeding this function will fail.

7. Price is affected by the density to which reserves are drilled and not by the reserves themselves.

8. The drilling of a large number of excess wells, despite the fact that it greatly increases unit costs, can have no natural effect on prices but that of depressing them. This should be of particular significance to the smaller units in the industry, dependent upon a reasonable current income.

9. Drilling cost represents about one-half of the current cost of producing oil and is the only item that can be readily reduced.

10. The cause of close drilling has been the type of proration methods employed.

11. Current proration formulas do not prorate on the basis of either the rule of capture or oil in place.

12. Proration on a basis of oil in place, or any other basis that achieves the same equity, coupled with wide-spacing rules, is a sound solution of the problem.

DISCUSSION

(Carl E. Reistle, Jr., presiding)

R. E. HARDWICKE, * Fort Worth, Tex.—Apparently there is little ground for doubting the accuracy of the statements of fact as given in Mr. Hubbard's paper. The trend is everywhere recognized. Rather disastrous results are almost inevitable, and, though the remedies for cushioning the shock are clear and have long been known, very little is being done about it. The apathy of the great majority of persons in the oil industry, in the face of such conditions, is difficult to understand.

The source of most of the trouble is excessive or unnecessary drilling, with the outstanding evils being (1) difficulty of production control and (2) unnecessary expense. It is obvious that the demand for crude has expanded but slightly while the net number of producing wells has increased greatly. The average allowable per well has steadily declined, with rapid approach to the critical point. A material increase in the over-all allowable, simply to raise the average in barrels of the per well allowable, would be unwise, for, apart from physical waste, price would surely decrease to an extent that the income would be less than that received with the lower allowable in effect. Production control becomes difficult under such conditions, for the competition between states, and between fields and areas in a state, for higher allowable at the expense of others becomes acute. The political phase of the problem becomes accentuated. Furthermore, the decreasing average allowable per well, resulting from excessive drilling and with no material increase in market demand creates a tendency for violation of proration orders.

The second prime evil resulting from many unnecessary wells is unnecessary expense. Assuming as correct the figures frequently given for the East Texas field, it appears that some 12,500 unnecessary wells have been drilled. Assuming the average cost to be \$13,000, it follows that 162 million dollars has been spent in drilling these 12,500 unnecessary wells. Taking 1935 as a basis, it appears that the price of oil was approximately \$1 per barrel, that the average daily production was about 435,000 bbl., or, in round numbers, 159,000,000 bbl. per year. From these calculations it appears that if the price of oil had been \$2 a barrel for 1935, the additional income to the operators from the 100 per cent increase in price would have been only 159 million dollars, which is less than the amount spent in drilling approximately 12,500 unnecessary wells. In other words, if the unnecessary wells had not been drilled, the operators as a whole would have saved 162 million dollars, being better off than if they had drilled the wells and received \$2 a barrel instead of \$1 a barrel for the 1935 production. It is very doubtful whether the ultimate recovery from the field will be any higher because these 12,500 wells were drilled, and it is almost certain that any increase in recovery will fall far short of repaying the expense of drilling and operating such wells. Similar conditions prevail in many fields, notably Oklahoma City.

* Hardwicke, Brelsford & Cheek.

Adopting the language of the economists, the oil industry at the present time is in a condition called "economy of abundance" instead of "economy of scarcity." The problem is to sell crude oil at a fair price instead of the problem of producing enough oil to supply an almost unlimited demand at a very profitable price. Partly because of such conditions, and partly because of a better appreciation of intelligent production methods, the old days of open-flow production and over-night millionaires are about gone. Adopting a trite expression, the oil business is now more of a business than a gamble. Operators are daily becoming convinced that profit must be sought by operating at less expense. Marketers, to increase sales, are almost reduced to the expediency of making a better product than their competitors. Clearly, much will be saved if fewer wells are drilled with no appreciable loss in ultimate recovery.

The remedy for decreasing the number of unnecessary wells appears to be quite plain: Mr. Hubbard points it out—a proration order which fairly distributes the allowable production for the field, virtually protecting against undue drainage, almost automatically stops unnecessary drilling. Each operator, under such an order, would not be required to drill unnecessary wells to get his fair share. Distribution of production on a flat per well basis, or on a potential basis where the spacing of wells is not uniform or is too dense, almost always results in inequities and in unnecessary drilling.

There seems to be little doubt that facts are now available for writing proration orders that minimize drilling and give each operator his fair share of the production. On the whole, the administrative bodies have done their part, but there still is room for substantial improvement.

A special Sub-Committee of Nine is now studying the evils of unnecessary drilling. Mr. Hubbard's paper will be of great assistance to the committee.¹

¹ The report of the Sub-Committee of Nine, Evils Attending Unnecessary Drilling in Proven Fields, and the Remedy, dated Dec. 1, 1936, has been published in full in the *Independent Monthly* (January 1937) and in the *Oil Weekly* (Dec. 28, 1936).

Acreage and Potential Factors in Allocation

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(Fort Worth Meeting, October, 1936)

THE writer apologizes for presenting this very elementary analysis of one aspect of proration, but a search of the literature failed to disclose any concrete illustrations of the effect of various proration formulas upon the allowable oil produced by tracts of different sizes. Many engineers have doubtless made somewhat similar calculations and are fully acquainted with the results.

The various allocation formulas that are in use are based on one or more of the following factors: (1) wide-open well potential, (2) potential through an orifice, (3) uniform well allowable, (4) acreage, (5) sand thickness, (6) bottom-hole pressure, (7) productivity index, and (8) volumetric displacement. Of these, the unrestricted potential formula, or open-flow test, and the uniform well allowable are commonly regarded by engineers as those least likely to give each producer his proportionate share of the oil or gas, as represented either by acreage or by sand thickness, or both, except when the wells are located on tracts of large size.

Unless the mechanical equipment that may be used during the potential test and the method of taking the test are both specified, the net result of the potential formula is to practically force the operators to use special equipment and adopt special procedures prior to and during the potential test, so as to secure the largest possible allowables. Much ingenuity and skill have been devoted to this problem, but the general effect is to permit excessive allowables for very small tracts, and stimulate unnecessary drilling.

It is interesting to compare some of the high yields from the Wilcox horizon at Oklahoma City with each other, as an illustration of the effect of an allocation factor based *solely on potential* (Table 5). One of the glaring instances is a well on a $\frac{1}{2}$ -acre lease, which had produced, as of September 1936, at the rate of almost 3,000,000 bbl. per acre. This is at least twice as many barrels as could have been present under the property if the reservoir had consisted of a tank of oil 200 ft. deep and $\frac{1}{2}$ acre in area.

Numerous combinations of acreage, potential, bottom-hole pressure, sand thickness, etc., have been proposed and are in use in various fields.

Manuscript received at the office of the Institute Oct. 9, 1936.

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One of the best formulas is that proposed by the allocation committee of the American Petroleum Institute, but even this one has been criticized, because it is based fundamentally on oil in place. The criticism is hardly deserved, since the ideal plan would be to preserve the property status that existed at the time the reservoir was tapped. Equity would give then to each producer either the exact amount of oil or gas that existed under his property at the date of discovery, or a rate of production bearing the same ratio to the total rate for the pool as his original oil or gas content bore to the original oil or gas in the entire pool.

It has been advocated by some that an allocation formula which gave weight to both acreage and potential would be equitable to all parties concerned, and the tables shown herewith have been calculated to show how such formulas affect the allowable production when the latter is expressed on a per acre basis. Four complete sets of calculations have been made, each consisting of five "cases" corresponding to five stages in the development of an imaginary field. The latter is assumed to include 600 acres initially, with a gradual expansion in size until complete development is reached at 8000 acres. The potential for the field is assumed to be 800 bbl. per hour at the 600-acre stage, and it gradually increases to 12,000 bbl. per hour when the field is fully developed. A corresponding change in the allowable is also assumed, starting at 12,000 bbl. per day and reaching a maximum of 72,000 bbl. per day when the field is developed.

Making use of these assumptions, the allowables have been computed that would result from allocation formulas which include both acreage and potential in the following proportions:

1. Allocations based on 50 per cent acreage and 50 per cent potential.
2. Allocations based on 75 per cent acreage and 25 per cent potential.
3. Allocations based on 25 per cent acreage and 75 per cent potential.
4. Allocations based on 90 per cent acreage and 10 per cent potential.

These formulas can all be expressed as follows:

$$Q = x \cdot B_f \left(\frac{P_w}{P_f} \right) + y B_f \left(\frac{A_w}{A_f} \right)$$

when Q = barrels per day allowable to *any well*,

x = percentage allocated to potential,

y = percentage allocated to acreage, and $x + y = 100$ per cent,

B_f = field allowable, barrels per day,

P_w = well potential, barrels per hour,

P_f = field potential, barrels per hour,

A_w = acres per well,

A_f = acres in field.

In order to show how these different formulas affect the allowable oil produced from tracts of different sizes, each one of the four has been

TABLE 1.—*Allocations Based on 50 Per Cent Acreage and 50 Per Cent Potential*

Number of Acres per Well	1			5			10			15			20		
	P	A	P + A	P	A	P + A	P	A	P + A	P	A	P + A	P	A	P + A
Daily Allowable per Wells															
Potential of Well, Bbl. per Hr.															
CASE I. DEVELOPED AREA OF FIELD, 600 ACRES; HOURLY POTENTIAL OF FIELD, 800 BBL.; DAILY ALLOWABLE OF FIELD, 12,000 BBL.															
10	75	10	85	75	50	125	75	100	175	75	150	225	75	200	275
15	112.5	10	122.5	112.5	50	172.5	112.5	100	212.5	112.5	150	262.5	112.5	200	312.5
20	150	10	160	150	50	200	150	100	250	150	150	300	150	200	360
25	187.5	10	197.5	187.5	50	237.5	187.5	100	287.5	187.5	150	337.5	187.5	200	387.5
30	225	10	235	225	50	275	225	100	325	225	150	375	225	200	425
Daily Allowable Production, Bbl. per Acre															
10	85			25			17.5			15			13.75		
15	122.5			32.5			21.25			17.5			15.625		
20	160			40			25			20			17.5		
25	197.5			47.5			28.75			22.5			19.375		
30	235			55			32.5			25			21.25		
Allowable per Acre as Percentage of Allowable per Acre for 20-acre Tract															
10	617			182			127			109			100		
15	785			208			136			112			100		
20	914			229			143			114			100		
25	1019			243			148			116			100		
30	1105			259			153			118			100		
CASE II. DEVELOPED AREA OF FIELD, 1200 ACRES; HOURLY POTENTIAL OF FIELD, 1500 BBL.; DAILY ALLOWABLE OF FIELD, 20,000 BBL.															
10	66.66	8.33	74.99	66.66	41.66	108.32	66.66	83.33	149.99	66.66	125	191.66	66.66	166.66	233.32
15	100.00	8.33	108.33	100.00	41.66	141.66	100.00	83.33	183.33	100.00	125	225.00	100.00	166.66	266.66
20	133.33	8.33	141.66	133.33	41.66	174.99	133.33	83.33	216.66	133.33	125	258.33	133.33	166.66	299.99
25	166.66	8.33	174.99	166.66	41.66	208.32	166.66	83.33	249.99	166.66	125	291.66	166.66	166.66	333.32
30	200.00	8.33	208.33	200.00	41.66	241.66	200.00	83.33	283.33	200.00	125	325.00	200.00	166.66	366.66
Daily Allowable Production, Bbl. per Acre															
10	75			21.66			15.00			12.77			11.66		
15	108.33			28.33			18.33			15.00			13.33		
20	141.67			35.00			21.66			17.22			15.00		
25	175.00			41.66			25.00			19.44			16.67		
30	208.33			48.33			28.33			21.67			18.33		
Allowable per Acre as Percentage of Allowable per Acre for 20-acre Tract															
10	642			186			128			109			100		
15	812			212			137			112			100		
20	944			233			144			115			100		
25	1050			250			150			116.6			100		
30	1137			263			154			118			100		
CASE III. DEVELOPED AREA OF FIELD, 3000 ACRES ^b ; HOURLY POTENTIAL OF FIELD, 4000 BBL.; DAILY ALLOWABLE OF FIELD, 30,000 BBL.															
10	37.5	5	42.5	37.5	25	62.5	37.5	50	87.5	37.5	75	112.5	37.5	100	137.5
15	36.25	5	41.25	36.25	25	61.25	36.25	50	86.25	36.25	75	111.25	36.25	100	136.25
20	75.00	5	80.00	75.00	25	100.00	75.00	50	125.00	75.00	75	150.00	75.00	100	175.00
25	93.75	5	90.75	93.75	25	118.75	93.75	50	143.75	93.75	75	168.75	93.75	100	193.75
30	112.5	5	117.5	112.5	25	137.5	112.5	50	162.5	112.5	75	187.5	112.5	100	212.5
Daily Allowable Production, Bbl. per Acre															
10	42.5			12.5			8.75			7.5			6.875		
15	61.25			16.25			10.625			8.75			7.812		
20	80			20			12.5			10.00			8.75		
25	98.75			23.75			14.375			11.25			9.687		
30	117.5			27.5			16.25			12.50			10.625		
Allowable per Acre as Percentage of Allowable per Acre for 20-acre Tract															
10	618			182			127			109			100		
15	785			208			136			112			100		
20	914			228			143			114			100		
25	1020			245			148			116			100		
30	1106			259			153			118			100		

^a In all tables included here, P, allowable due to potential, bbl. per well per day; A, allowable due to acreage, bbl. per well per day; P + A, total allowable, bbl. per well per day.

^b Or 6000 acres, 8000 bbl. and 60,000 bbl.

TABLE 1.—(Continued)

Number of Acres per Well	1			5			10			15			20		
	Daily Allowable per Well ^a														
Potential of Well, Bbl. per Hr.	P	A	P + A	P	A	P + A	P	A	P + A	P	A	P + A	P	A	P + A

CASE IV. DEVELOPED AREA OF FIELD, 8000 ACRES; HOURLY POTENTIAL OF FIELD, 10,000 BBL.; DAILY ALLOWABLE OF FIELD, 60,000 BBL.

10	30	3.75	33.75	30	18.75	48.75	30	37.5	67.5	30	56.25	86.25	30	75	105
15	45	3.75	48.75	45	18.75	63.75	45	37.5	82.5	45	56.25	101.25	45	75	120
20	60	3.75	63.75	60	18.75	78.75	60	37.5	97.5	60	56.25	116.25	60	75	135
25	75	3.75	78.75	75	18.75	93.75	75	37.5	112.5	75	56.25	131.25	75	75	150
30	90	3.75	93.75	90	18.75	108.75	90	37.5	127.5	90	56.25	146.25	90	75	165

Daily Allowable Production, Bbl. per Acre

10	33.75	9.75	6.75	5.75	5.25
15	48.75	12.75	8.25	6.75	6.00
20	63.75	15.75	9.75	7.75	6.75
25	78.75	18.75	11.25	8.75	7.50
30	93.75	21.75	12.75	9.75	8.25

Allowable per Acre as Percentage of Allowable per Acre for 20-acre Tract

10	642	185	120	109.5	100
15	812	212	137	112	100
20	945	233	144	115	100
25	1050	250	150	116	100
30	1135	264	155	118	100

CASE V. DEVELOPED AREA OF FIELD, 8000 ACRES; HOURLY POTENTIAL OF FIELD, 12,000 BBL.; DAILY ALLOWABLE OF FIELD, 72,000 BBL.

10	30	4.5	34.5	30	22.5	52.5	30	45	75	30	67.5	97.5	30	90	120
15	45	4.5	49.5	45	22.5	67.5	45	45	90	45	67.5	112.5	45	90	135
20	60	4.5	64.5	60	22.5	82.5	60	45	105	60	67.5	127.5	60	90	150
25	75	4.5	79.5	75	22.5	97.5	75	45	120	75	67.5	142.5	75	90	165
30	90	4.5	94.5	90	22.5	112.5	90	45	135	90	67.5	157.5	90	90	180

Daily Allowable Production, Barrels per Acre

10	34.5	10.5	7.5	6.5	6.00
15	49.5	13.5	9.0	7.5	6.75
20	64.5	16.5	10.5	8.5	7.50
25	79.5	19.5	12.0	9.5	8.25
30	94.5	22.5	13.5	10.5	9.00

Allowable per Acre as Percentage of Allowable per Acre for 20-acre Tract

10	575	175	125	108	100
15	734	200	133	111	100
20	860	220	140	113	100
25	964	236	145	115	100
30	1050	250	150	117	100

applied to tracts of 1, 5, 10, 15 and 20 acres, with the well potentials ranging from 10 to 30 bbl. per hour. To compare the yields per acre that result from application of the various formulas, the allowable per acre from a 20-acre unit has been considered as 100 per cent and the allowable per acre from the smaller tracts expressed as percentage thereof.

In every case, the advantages possessed by the owner of a one-acre tract are great. With a well having a potential of 10 bbl. per hour, he

TABLE 2.—*Allocations Based on 75 Per Cent Acreage and 25 Per Cent Potential*

Number of Acres per Well	1			5			10			15			20		
	Daily Allowable per Well ^a			Daily Allowable per Well ^a			Daily Allowable per Well ^a			Daily Allowable per Well ^a			Daily Allowable per Well ^a		
	P	A	P+A	P	A	P+A	P	A	P+A	P	A	P+A	P	A	P+A
Potential of Well, Bbl. per Hr.															
CASE I. DEVELOPED AREA OF FIELD, 600 ACRES; HOURLY POTENTIAL OF FIELD, 800 BBL.; DAILY ALLOWABLE OF FIELD, 12,000 BBL.															
10	37.5	15	52.5	37.5	75	112.5	37.5	150	187.5	37.5	225	262.5	37.5	300	337.5
15	56.3	15	71.3	56.3	75	131.3	56.3	150	206.3	56.3	225	281.3	56.3	300	356.3
20	75	15	90	75	75	150	75	150	225	75	225	300	75	300	375
25	93.7	15	108.7	93.7	75	168.7	93.7	150	243.7	93.7	225	318.7	93.7	300	393.7
30	112.5	15	127.5	112.5	75	187.5	112.5	150	262.5	112.5	225	337.5	112.5	300	412.5
Daily Allowable Production, Bbl. per Acre															
10		52.5			22.5			18.75			17.5			16.87	
15		71.3			26.2			20.63			18.75			17.81	
20		90			30.0			22.50			20.00			18.75	
25		108.7			33.7			24.37			21.22			19.68	
30		127.5			37.5			26.25			22.23			20.62	
Allowable per Acre as Percentage of Allowable per Acre for 20-acre Tract															
10		311			133			111			104			100	
15		400			147			116			105			100	
20		480			160			120			106			100	
25		552			171			124			108			100	
30		618			182			127			108			100	
CASE II. DEVELOPED AREA OF FIELD, 1200 ACRES; HOURLY POTENTIAL OF FIELD, 1500 BBL.; DAILY ALLOWABLE OF FIELD, 20,000 BBL.															
10	33.3	12.5	45.8	33.3	62.5	95.8	33.3	125	158.3	33.3	187.5	220.8	33.3	250	283.3
15	50	12.5	62.5	50	62.5	112.5	50	125	175	50	187.5	237.5	50	250	300
20	66.6	12.5	79.1	66.6	62.5	129.1	66.6	125	191.6	66.6	187.5	254.1	66.6	250	316.6
25	83.3	12.5	95.8	83.3	62.5	145.8	83.3	125	208.3	83.3	187.5	270.8	83.3	250	333.3
30	100	12.5	112.5	100	62.5	162.5	100	125	225	100	187.5	287.5	100	250	350
Daily Allowable Production, Bbl. per Acre															
10		45.8			19.2			15.8			14.7			14.1	
15		62.5			22.5			17.5			15.8			15.0	
20		79.1			25.8			19.2			16.9			15.8	
25		95.8			29.1			20.8			18			16.6	
30		112.5			32.5			22.5			19.1			17.5	
Allowable per Acre as Percentage of Allowable per Acre for 20-acre Tract															
10		325			136			112			104			100	
15		417			150			117			105			100	
20		500			163			121			107			100	
25		576			175			125			108			100	
30		643			186			128			109			100	
CASE III. DEVELOPED AREA OF FIELD, 3000 ACRES; HOURLY POTENTIAL OF FIELD, 4000 BBL.; DAILY ALLOWABLE OF FIELD, 30,000 BBL.															
10	18.7	7.5	26.2	18.7	37.5	56.2	18.7	75	93.7	18.7	112.5	131.2	18.7	150	168.7
15	28.1	7.5	35.6	28.1	37.5	65.6	28.1	75	103.1	28.1	112.5	140.6	28.1	150	178.1
20	37.5	7.5	45.0	37.5	37.5	75	37.5	75	112.5	37.5	112.5	150	37.5	150	187.5
25	46.8	7.5	54.3	46.8	37.5	84.3	46.8	75	121.8	46.8	112.5	159.3	46.8	150	196.8
30	56.2	7.5	63.7	56.2	37.5	93.7	56.2	75	131.2	56.2	112.5	168.7	56.2	150	206.2
Daily Allowable Production, Bbl. per Acre															
10		26.2			11.2			9.37			8.75			8.43	
15		35.6			13.1			10.31			9.37			8.90	
20		45.0			15.0			11.25			10.00			9.37	
25		54.3			16.8			12.18			10.60			9.84	
30		63.7			18.7			13.13			11.24			10.31	
Allowable per Acre as Percentage of Allowable per Acre for 20-acre Tract															
10		311			133			112			105			100	
15		400			147			116			106			100	
20		480			160			120			107			100	
25		552			171			124			108			100	
30		618			181			127			109			100	

TABLE 2.—(Continued)

Number of Acres per Well	1			5			10			15			20		
Daily Allowable per Well ^a															
Potential of Well, Bbl. per Hr.	P	A	P + A	P	A	P + A	P	A	P + A	P	A	P + A	P	A	P + A

CASE IV. DEVELOPED AREA OF FIELD, 8000 ACRES; HOURLY POTENTIAL OF FIELD, 10,000 BBL.; DAILY ALLOWABLE OF FIELD, 50,000 BBL.

10	12.5	4.7	17.2	12.5	23.5	36	12.5	47	59.5	12.5	70.5	83.0	12.5	94	106.5
15	18.7	4.7	23.4	18.7	23.5	42.2	18.7	47	65.7	18.7	70.5	89.2	18.7	94	112.7
20	25	4.7	29.7	25	23.5	48.5	25	47	72.0	25	70.5	95.5	25	94	119.0
25	31.2	4.7	35.9	31.2	23.5	54.7	31.2	47	78.2	31.2	70.5	101.7	31.2	94	125.2
30	37.5	4.7	42.2	37.5	23.5	61.0	37.5	47	84.5	37.5	70.5	108.0	37.5	94	131.5

Daily Allowable Production, Bbl. per Acre

10	17.2	7.2	5.95	5.53	5.32
15	23.4	8.4	6.57	5.94	5.63
20	29.7	9.7	7.20	6.36	5.95
25	35.9	10.9	7.82	6.78	6.25
30	42.2	12.2	8.45	7.20	6.57

Allowable per Acre as Percentage of Allowable per Acre for 20-acre Tract

10	323	135	112	104	100
15	415	149	117	105	100
20	500	163	121	107	100
25	574	174	125	108	100
30	642	186	128	109	100

CASE V. DEVELOPED AREA OF FIELD, 8000 ACRES; HOURLY POTENTIAL OF FIELD, 12,000 BBL.; DAILY ALLOWABLE OF FIELD, 72,000 BBL.

10	15	6.75	21.75	15	33.7	48.7	15	67.5	82.5	15	101.2	116.2	15	135	150
15	22.5	6.75	29.25	22.5	33.7	56.2	22.5	67.5	90	22.5	101.2	123.7	22.5	135	157.5
20	30	6.75	36.75	30	33.7	63.7	30	67.5	97.5	30	101.2	131.2	30	135	165
25	37.5	6.75	44.25	37.5	33.7	71.2	37.5	67.5	105.0	37.5	101.2	138.7	37.5	135	172.5
30	45	6.75	51.75	45	33.7	78.7	45	67.5	112.5	45	101.2	146.2	45	135	180

Daily Allowable Production, Bbl. per Acre

10	21.75	9.75	8.25	7.75	7.5
15	29.25	11.25	9.00	8.25	7.87
20	36.75	12.75	9.75	8.75	8.25
25	44.25	14.25	10.50	9.25	8.62
30	51.75	15.75	11.25	9.75	9.00

Allowable per Acre as Percentage of Allowable per Acre for 20-acre Tract

10	290	130	110	103	100
15	372	143	114	104	100
20	445	155	118	106	100
25	513	165	122	107	100
30	575	175	125	108	100

may produce from 300 to over 1000 per cent as much oil per day from his one acre as the operator on a 20-acre tract may produce per acre. If his well has a potential of 30 bbl. per hour, he may produce from 300 to nearly 1600 per cent as much per acre per day as the operator on a 20-acre tract, with a well of the same capacity. The higher the potential,

TABLE 3.—*Allocations Based on 25 Per Cent Acreage and 75 Per Cent Potential*

Number of Acres per Well	1			5			10			15			20		
	P	A	P+A	P	A	P+A	P	A	P+A	P	A	P+A	P	A	P+A
Potential of Well, Bbl. per Hr.															
CASE I. DEVELOPED AREA OF FIELD, 600 ACRES; HOURLY POTENTIAL OF FIELD, 800 BBL.; DAILY ALLOWABLE OF FIELD, 12,000 BBL.															
10	112.5	5	117.5	112.5	25	137.5	112.5	50	162.5	112.5	75	187.5	112.5	100	212.5
15	168.8	5	173.8	168.8	25	193.8	168.8	50	218.8	168.8	75	243.8	168.8	100	268.8
20	225.0	5	230.0	225.0	25	250.0	225.0	50	275.0	225.0	75	300.0	225.0	100	325.0
25	281.2	5	286.2	281.2	25	306.2	281.2	50	331.2	281.2	75	356.2	281.2	100	381.5
30	337.5	5	342.5	337.5	25	362.5	337.5	50	387.5	337.5	75	412.5	337.5	100	437.5
Daily Allowable Production, Bbl. per Acre															
10	117.5			25.5			16.3			12.5			10.6		
15	173.8			38.7			21.9			16.2			13.4		
20	230.0			50.0			27.5			20.0			16.2		
25	286.2			61.2			33.1			23.8			19.1		
30	342.5			72.5			38.6			27.5			21.8		
Daily Allowable per Acre as Percentage of Allowable per Acre per Day for 20-acre Tract															
10	1108.0			241.0			153.8			118.0			100		
15	1295.0			288.5			163.4			120.8			100		
20	1420.0			308.5			169.8			123.5			100		
25	1500.0			320.0			173.2			124.7			100		
30	1570.0			332.0			177.0			126.2			100		
CASE II. DEVELOPED AREA OF FIELD, 1200 ACRES; HOURLY POTENTIAL OF FIELD, 1500 BBL.; DAILY ALLOWABLE OF FIELD, 20,000 BBL.															
10	100	4.2	104.2	100	20.8	120.8	100	41.6	141.6	100	63.8	163.8	100	83.3	183.3
15	150	4.2	154.2	150	20.8	170.8	150	41.6	191.6	150	63.8	213.8	150	83.3	233.3
20	200	4.2	204.2	200	20.8	220.8	200	41.6	241.6	200	63.8	263.8	200	83.3	283.3
25	250	4.2	254.2	250	20.8	270.8	250	41.6	291.6	250	63.8	313.8	250	83.3	333.3
30	300	4.2	304.2	300	20.8	320.8	300	41.6	341.6	300	63.8	363.8	300	83.3	383.3
Daily Allowable Production, Bbl. per Day															
10	104.2			24.1			14.2			10.9			9.2		
15	154.2			34.1			19.2			14.2			11.6		
20	204.2			44.1			24.2			17.6			14.2		
25	254.2			54.1			29.2			20.9			16.6		
30	304.2			64.1			34.2			24.2			19.2		
Daily Allowable per Acre as Percentage of Allowable per Acre for 20-acre Tract															
10	1132			262.0			154.5			118.5			100		
15	1330			294.0			165.5			122.5			100		
20	1440			310.6			170.5			124.0			100		
25	1533			325.5			176.0			126.0			100		
30	1588			334.2			178.4			126.2			100		
CASE III. DEVELOPED AREA OF FIELD, 3000 ACRES; HOURLY POTENTIAL OF FIELD, 12,000 BBL.; DAILY ALLOWABLE OF FIELD, 30,000 BBL.															
10	18.8	2.5	21.3	18.8	12.5	31.3	18.8	25	43.8	18.8	37.5	56.3	18.8	50	68.8
15	28.1	2.5	30.6	28.1	12.5	40.6	28.1	25	53.1	28.1	37.5	65.6	28.1	50	78.1
20	37.5	2.5	40.0	37.5	12.5	50.0	37.5	25	62.5	37.5	37.5	75.0	37.5	50	87.5
25	46.9	2.5	49.4	46.9	12.5	59.4	46.9	25	71.9	46.9	37.5	84.4	46.9	50	96.9
30	56.2	2.5	58.7	56.2	12.5	68.7	56.2	25	81.2	56.2	37.5	93.7	56.2	50	106.2
Daily Allowable Production, Bbl. per Acre															
10	21.3			6.3			4.4			3.6			3.4		
15	30.6			8.1			5.3			4.4			3.9		
20	40.0			10.0			6.3			5.0			4.4		
25	49.4			11.9			7.2			5.6			4.8		
30	58.7			13.7			8.1			6.3			5.3		
Daily Allowable per Acre as Percentage of Allowable per Acre per Day for 20-acre Tract															
10	627			185.1			129.3			106.0			100		
15	785			207.5			135.8			112.8			100		
20	908			227			143.0			113.6			100		
25	1030			247.8			149.8			116.7			100		
30	1107			268.5			152.7			118.8			100		

TABLE 3.—(Continued)

Number of Acres per Well	1			5			10			15			20		
Daily Allowable per Well ^a															
Potential of Well, Bbl. per Hr.	P	A	P + A	P	A	P + A	P	A	P + A	P	A	P + A	P	A	P + A

CASE IV. DEVELOPED AREA OF FIELD, 8000 ACRES; HOURLY POTENTIAL OF FIELD, 10,000 BBL.; DAILY ALLOWABLE OF FIELD, 60,000 BBL.

10	45.0	1.9	46.9	45.0	9.3	54.3	45.0	18.5	63.5	45.0	27.8	72.8	45.0	37.0	82.0
15	67.5	1.9	69.4	67.5	9.3	96.8	67.5	18.5	86.0	67.5	27.8	95.3	67.5	37.0	104.5
20	90.0	1.9	91.9	90.0	9.3	99.3	90.0	18.5	108.5	90.0	27.8	117.8	90.0	37.0	127.0
25	112.5	1.9	114.4	112.5	9.3	121.8	112.5	18.5	131.0	112.5	27.8	140.3	112.5	37.0	149.5
30	135.0	1.9	136.9	135.0	9.3	144.3	135.0	18.5	153.5	135.0	27.8	162.8	135.0	37.0	172.0

Daily Allowable Production, Bbl. per Acre

10	46.9	10.9	6.4	4.9	4.1
15	69.4	15.4	8.6	6.4	5.2
20	91.9	19.9	10.9	7.8	6.4
25	114.4	24.4	13.1	9.4	7.5
30	136.9	28.9	15.4	10.8	8.6

Daily Allowable per Acre as Percentage of Allowable per Acre per Day for 20-acre Tract

10	1143	266.0	156.5	119.5	100
15	1360	296.0	168.5	125.5	100
20	1435	311.0	170.0	122.0	100
25	1524	325.5	174.8	125.3	100
30	1590	336.0	179.0	125.5	100

CASE V. DEVELOPED AREA OF FIELD, 8000 ACRES; HOURLY POTENTIAL OF FIELD, 12,000 BBL.; DAILY ALLOWABLE OF FIELD, 72,000 BBL.

10	45.0	2.3	47.3	45.0	11.3	56.3	45.0	22.5	67.5	45.0	33.8	78.8	45.0	45.0	90.0
15	67.5	2.3	69.8	67.5	11.3	78.8	67.5	22.5	90.0	67.5	33.8	101.3	67.5	45.0	112.5
20	90.0	2.3	92.3	90.0	11.3	101.3	90.0	22.5	112.5	90.0	33.8	123.8	90.0	45.0	135.0
25	112.5	2.3	114.8	112.5	11.3	123.8	112.5	22.5	135.0	112.5	33.8	146.3	112.5	45.0	157.5
30	135.0	2.3	137.3	135.0	11.3	146.3	135.0	22.5	157.5	135.0	33.8	168.8	135.0	45.0	180.0

Daily Allowable Production, Bbl. per Hour

10	47.3	11.3	6.8	5.3	4.5
15	69.8	15.8	9.0	6.7	5.6
20	92.3	20.3	11.3	8.2	6.8
25	114.8	24.8	13.5	9.8	7.9
30	137.3	29.3	15.8	11.3	9.0

Daily Allowable per Acre as Percentage of Allowable per Acre per Day for 20-acre Tract

10	1051	251.0	151.2	117.8	100
15	1247	282.0	161.0	119.6	100
20	1358	298.5	166.0	120.5	100
25	1451	314.0	171.0	124.0	100
30	1525	325.5	175.6	125.5	100

the greater becomes the difference in the allowable per acre, even for wells of the same capacity. Smaller differentials will exist as less weight is given to potential and more to acreage, as is shown in the "cases" of 90 per cent acreage and 10 per cent potential, but even then the one-acre tract has an allowable ranging from 175 to 325 per cent per acre in comparison with similar wells on the 20-acre unit.

TABLE 4.—*Allocations Based on 90 Per Cent Acreage and 10 Per Cent Potential*

Number of Acres per Well	1			5			10			15			20		
	P	A	P + A	P	A	P + A	P	A	P + A	P	A	P + A	P	A	P + A
Potential of Well, Bbl. per Hr.															
CASE I. DEVELOPED AREA OF FIELD, 600 ACRES; HOURLY POTENTIAL OF FIELD, 800 BBL.; DAILY ALLOWABLE OF FIELD, 12,000 BBL.															
10	15	18	33	15	90	105	15	180	195	15	270	285	15	360	375
15	22.5	18	40.5	22.5	90	112.5	22.5	180	202.5	22.5	270	292.5	22.5	360	382.5
20	30	18	48	30	90	120	30	180	210	30	270	300	30	360	390
25	37.5	18	55.5	37.5	90	127.5	37.5	180	217.5	37.5	270	307.5	37.5	360	397.5
30	45	18	63	45	90	135	45	180	225	45	270	315	45	360	405
Daily Allowable Production, Bbl. per Acre															
10		33			21			19.5			19			18.75	
15		40.5			22.5			20.25			19.5			19.15	
20		48			24			21			20			19.5	
25		55.5			25.5			21.75			20.5			19.875	
30		63			27			22.5			21.0			20.25	
Daily Allowable per Acre as Percentage of Allowable per Acre for 20-acre Tract															
10		176			112			104			101.3			100	
15		211.4			117.5			105.7			101.8			100	
20		246.1			123			107.7			102.5			100	
25		279.2			128.3			109.4			103.1			100	
30		311.1			133.3			111.1			103.7			100	
CASE II. DEVELOPED AREA OF FIELD, 1200 ACRES; HOURLY POTENTIAL OF FIELD, 1500 BBL.; DAILY ALLOWABLE OF FIELD, 20,000 BBL.															
10	13.33	15	28.33	13.33	75	88.33	13.33	150	163.33	13.33	225	238.33	13.33	300	313.33
15	20	15	35	20	75	95	20	150	170	20	225	245	20	300	320
20	26.66	15	41.66	26.66	75	101.66	26.66	150	176.66	26.66	225	251.66	26.66	300	326.66
25	33.33	15	48.33	33.33	75	108.33	33.33	150	183.33	33.33	225	258.33	33.33	300	333.33
30	40	15	55	40	75	115	40	150	190	40	225	265	40	300	340
Daily Allowable Production, Bbl. per Acre															
10		28.33			17.66			16.33			15.88			15.66	
15		35			19			17			16.33			16	
20		41.66			20.33			17.66			16.76			16.33	
25		48.33			21.66			18.33			17.22			16.66	
30		55			23			19			17.66			17	
Allowable per Acre as Percentage of Allowable per Acre for 20-acre Tract															
10		181			113			104			101			100	
15		219			119			106			102			100	
20		255			124			108			102			100	
25		290			130			110			103			100	
30		323			135			111			104			100	
CASE III. DEVELOPED AREA OF FIELD, 3000 ACRES; HOURLY POTENTIAL OF FIELD, 12,000 BBL.; DAILY ALLOWABLE OF FIELD, 30,000 BBL.															
10	7.5	9	16.5	7.5	45	52.5	7.5	90	97.5	7.5	135	142.5	7.5	180	187.5
15	11.25	9	20.25	11.25	45	56.25	11.25	90	101.25	11.25	135	146.25	11.25	180	191.25
20	15	9	24.25	15	45	60	15	90	105	15	135	150	15	180	195
25	18.75	9	27.75	18.75	45	63.75	18.75	90	108.75	18.75	135	153.75	18.75	180	198.75
30	22.5	9	31.5	22.5	45	67.5	22.5	90	112.5	22.5	135	157.5	22.5	180	202.5
Daily Allowable Production, Bbl. per Acre															
10		16.5			10.5			9.75			9.5			9.37	
15		20.25			11.25			10.13			9.75			9.56	
20		24.25			12			10.5			10			9.75	
25		27.75			12.75			10.88			10.25			9.93	
30		31.5			13.5			11.25			10.5			10.12	
Daily Allowable per Acre as Percentage of Daily Allowable per Acre for 20-acre Tract															
10		176			112			104			101			100	
15		212			118			106			102			100	
20		249			123			108			103			100	
25		279			128			110			103			100	
30		311			133			111			104			100	

TABLE 4.—(Continued)

Number of Acres per Well	1			5			10			15			20		
	P	A	P + A	P	A	P + A	P	A	P + A	P	A	P + A	P	A	P + A
Daily Allowable per Well ^a															
Potential of Well, Bbl. per Hr.															

CASE IV. DEVELOPED AREA OF FIELD, 8000 ACRES; HOURLY POTENTIAL OF FIELD, 10,000 BBL.; DAILY ALLOWABLE OF FIELD, 60,000 BBL.

10	6	6.75	12.75	6	33.75	39.75	6	67.5	73.5	6	101.25	107.25	6	135	141
15	9	6.75	15.75	9	33.75	42.75	9	67.5	76.5	9	101.25	110.25	9	135	144
20	12	6.75	18.75	12	33.75	45.75	12	67.5	79.5	12	101.25	113.25	12	135	147
25	15	6.75	21.75	15	33.75	48.75	15	67.5	82.5	15	101.25	116.25	15	135	150
30	18	6.75	24.75	18	33.75	51.75	18	67.5	85.5	18	101.25	119.25	18	135	153

Daily Allowable Production, Bbl. per Acre

10	12.75	7.95	7.35	7.15	7.05
15	15.75	8.55	7.65	7.35	7.2
20	18.75	9.15	7.95	7.55	7.35
25	21.75	9.75	8.25	7.75	7.5
30	24.75	10.35	8.55	7.95	7.65

Daily Allowable per Acre as Percentage of Daily Allowable per Acre for 20-acre Tract

10	181	112	104	101	100
15	219	119	106	102	100
20	255	124	108	103	100
25	290	130	110	103	100
30	324	135	112	104	100

CASE V. DEVELOPED AREA OF FIELD, 8000 ACRES; HOURLY POTENTIAL OF FIELD, 12,000 BBL.; DAILY ALLOWABLE OF FIELD, 72,000 BBL.

10	6	8.1	14.1	6	40.5	46.5	6	81	87	6	121.5	127.5	6	162	168
15	9	8.1	17.1	9	40.5	49.5	9	81	90	9	121.5	130.5	9	162	171
20	12	8.1	21.1	12	40.5	52.5	12	81	93	12	121.5	133.5	12	162	174
25	15	8.1	23.1	15	40.5	55.5	15	81	96	15	121.5	136.5	15	162	177
30	18	8.1	26.1	18	40.5	58.5	18	81	99	18	121.5	139.5	18	162	180

Daily Allowable Production, Bbl. per Acre

10	14.1	9.3	8.7	8.5	8.4
15	17.1	9.9	9	8.7	8.55
20	20.1	10.5	9.3	8.9	8.7
25	23.1	11.1	9.6	9.1	8.85
30	26.1	11.7	9.9	9.3	9

Daily Allowable per Acre as Percentage of Daily Allowable per Acre for 20-acre Tract

10	168	111	104	101	100
15	200	116	105	102	100
20	231	121	107	102	100
25	261	125	108.5	103	100
30	290	130	110	103	100

^aP, allowable due to potential, bbl. per day; A, allowable due to acreage, bbl. per day; P + A, total allowable, bbl. per well per day.

TABLE 5.—Relations in Oklahoma City Field

Company	Well	Com- pletion Date	Initial Rock Pressure, Lb. per Sq. In.	Initial Poten- tial, 4-hr. Gauge	Size of Lease, Acres	Name of Pro- ducing Zone	Total Production to Sept. 1, 1936	Barrels per Acre
Minnehoma....	Pugh No. 1	9-17-30		10,879	2½	Wilcox	892,854	357,141
Oils, Inc.....	Ross	10-4-30	2,100	9,441	½	Wilcox	1,462,277	2,924,554
Phillips.....	Gallman No. 1	1-20-32	1,500	9,754	5	Wilcox	867,393	173,478
Phillips.....	McBeth No. 1	3-28-31	1,500	15,091	5	Wilcox	1,048,287	209,657
Grison.....	Turner No. 1	5-4-32	2,300	14,747	5	Wilcox	1,303,099	271,819
Phillips.....	Trail No. 1	10-9-32	1,500	5,826	5	Wilcox	995,039	199,007

A study of the allowables per acre for 5-acre tracts, in comparison with the per acre allowables of a 20-acre tract as the unit, also shows that the allowable for the smaller tract is from 133 to 350 per cent higher, dependent on the potential of the wells. Even the 10-acre tract has per acre allowables up to as much as 180 per cent of those of the 20-acre unit. The percentages increase as the potentials go up, and the question may well be raised as to whether potential has any place at all in an allocation formula.

Table 5 shows the relation between well potential, acreage, total production and barrels per acre for a few small tracts in the Oklahoma City field. In these instances, allocation is based on potential alone without regard to the number of acres on which the well is located, and without regard to any other of the factors that might influence ultimate recovery.

The bearing of these results upon the "law of capture" in practical oil-field operations is so obvious that it would appear to be part of the responsibility of every engineer to impress upon operators, royalty owners, legislative bodies and regulatory commissions the injustice of allocations based even in part on "potential" tests. Such inequities may be viciously intensified by excess drilling or too close spacing.

Until recent years spacing programs have been based chiefly on custom and expediency, with a minimum of experimental effort. The legal background which in large part served to perpetuate these customs originated long before the fundamental engineering principles of oil and gas production were known. But the wealth of information available today concerning the nature of oil and gas reservoirs, the physical and chemical properties of the reservoir fluids, their mutual solubility relations as functions of temperature, pressure and concentration, the mechanics of the expulsive forces, together with sound concepts of porosity and permeability, make the analogy between the migration of animals and the movement of oil and gas both ludicrous and untenable.

In fields where engineering viewpoints receive sufficient recognition, it has been found that periodic measurements of equilibrium relations within the reservoirs themselves, when combined with production data and reasonably accurate information as to sand thicknesses, properties of the reservoir rocks and their fluid contents, furnish ample data for the estimation of the quantities of oil and gas present, as of any particular date, in almost any portion of the reservoirs. The computations can be made with a degree of accuracy which is sufficiently precise to establish a basis for equitable allocation of the production to the owners of the oil and gas in place. No sound reasons can be vouched for permitting the development of small tracts, whether owned by major companies or minor ones, in such a way that they will be allowed to produce at per acre rates which unquestionably drain oil or gas or both, across property lines.

Cooperative Development Plan for Buena Vista Hills Oil and Gas Field, Kern County, California

BY C. M. NICKERSON,* MEMBER A.I.M.E.

(Los Angeles Meeting, October, 1936)

THE possibility of deeper production in the Buena Vista Hills was first considered in 1933. At that time, however, the heavy state curtailment program served to deter any operator from drilling test wells, which, if successful, might upset the proration schedules. Because most of the acreage was held by several major operators and the remainder by substantial independents, the adoption of a plan of cooperative development was considered desirable. Such a plan was formulated for the development of any deeper oil and gas horizons that may be found to exist. This plan, which was signed by the Secretaries of the Navy and of the Interior on behalf of the United States on July 9, 1936, is now effective for the development of lands within the area shown on Fig. 1. Unlike most unit plans, the present cooperative development plan permits each operator to drill and produce his own wells.

For the purpose of this plan the Buena Vista Hills field is divided into two pools. The present production is classed as the "old pool," while any future production below a certain marker which roughly coincides with the bottom of the Santa Margarita formation is included in the "pool" to which the provisions particularly apply.

Naval Petroleum Reserve No. 2 lies within the area and constitutes the major portion of the Federal leases subject to the plan. There are 39,040 acres and 27 operators within the area. Twenty-six operators controlling 99.5 per cent of the acreage have signed the agreement.

GEOLOGY OF THE BUENA VISTA HILLS

The Buena Vista Hills consist of a low range in the southern portion of the San Joaquin Valley, and are roughly parallel to the adjacent Temblor range to the south. The Elk Hills oil field parallels the Buena Vista Hills a few miles to the north.

The subsurface structure is a re-entrant anticline upon the major Midway-Sunset monocline. This anticline is divided into two minor

The views expressed herein are the author's only, and not necessarily those of the Navy Department. Manuscript received at the office of the Institute Oct. 13, 1936.

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structures, the United anticline in the western half of the field and the Honolulu anticline in the eastern half. Production is almost continuous over these anticlines.

The present oil-producing measures are found in the Etchegoin formation of Pliocene age, with a dry gas zone of limited extent overlying the crests of the United and Honolulu anticlines. The Sealez and sub-Mulinia oil zones are the source of the major portion of the oil produced in this field at the present time, with some production from the Santa Margarita formation on the south flank.

In the lower half of the Monterey group lenticular oil-sand bodies may exist. Geologists estimate that oil measures may exist in the *Valvulineria robusta* zone, middle Miocene age, at a depth of about 7500 ft.; at the base of the Temblor formation, lower Miocene age, at a depth of about 9000 ft.; and at the base of the Vaqueros formation, lower Miocene age, which is believed to be nearly 10,000 ft. from the surface at the crest of the structure. The Oligocene and Eocene age formations may contain oil and gas measures. The depths to these formations may be well below 10,000 feet.

ACREAGE WITHIN BUENA VISTA HILLS FIELD

There are 39,040 acres of land within the area included in the cooperative development plan for the Buena Vista Hills oil and gas field (Fig. 1). Of this acreage, 24,640 acres, or 63.1 per cent are owned in fee, 10,800 acres, or 27.7 per cent, are U. S. Navy fee or leased lands, and 3600 acres, or 9.2 per cent, are under lease from the Department of the Interior.

TABLE 1.—*Operators in Area*

Operator	Acres	Per Cent	Operator	Acres	Per Cent
Standard Oil Company of California.....	20,550	52.64	Claude R. Blodgett, Trustee.....	640	1.64
Honolulu Oil Corporation, Ltd.....	4,120	10.55	Midway Basin Oil Company.....	640	1.64
North American Oil Consolidated.....	3,240	8.30	The Texas Company.....	580	1.49
Murvale Oil Company....	1,980	5.07	Maricopa Investment Company.....	500	1.28
Associated Oil Company...	1,280	3.28	Rio Bravo Pioneer Oil Company.....	400	1.03
U. S. Navy (fee).....	1,220	3.13	United Oil Company....	400	1.03
General Petroleum Corporation.....	920	2.36	Others, 13 in number...	1,770	4.53
Union Oil Company.....	800	2.04			
				39,040	100.00

Table 1 shows the distribution of this area by operators, excluding holdings of less than 1 per cent. This table is based on an ideal section of

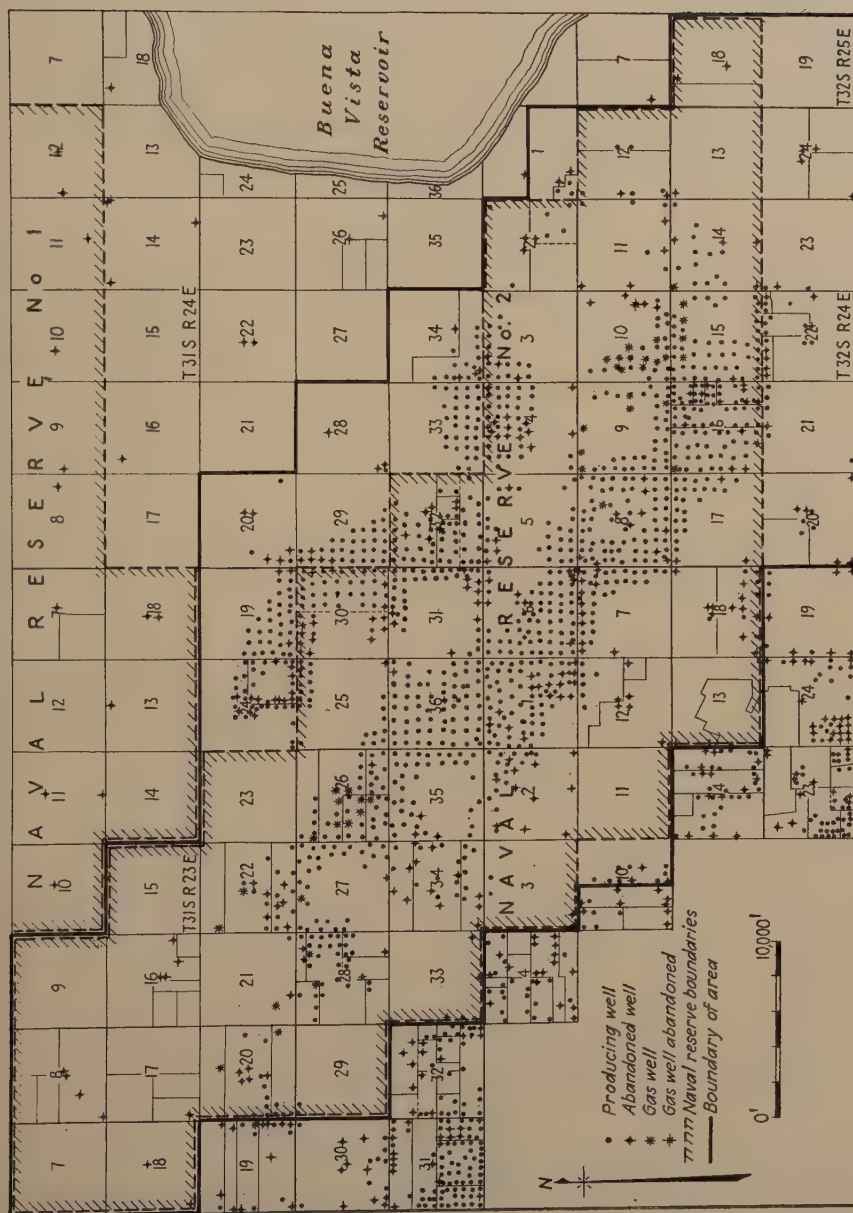


FIG. 1.—AREA OF BUENA VISTA HILLS OIL AND GAS FIELD, KERN COUNTY, CALIFORNIA.

640 acres each. As the need arises the actual acreage of each signatory party will be determined. The cooperative plan provides that as the field is developed and the limits of production are determined, owners of unproductive acreage will be eliminated from exercising a vote in the determination of problems arising in the field. The adoption of any uniform drilling or producing practice requires the affirmative vote of the operators holding 80 per cent of the acreage within the area.

SPACING OF WELLS

Under the cooperative plan of development of the deeper zones in the Buena Vista Hills oil field, operating units of 160 acres each, or one-

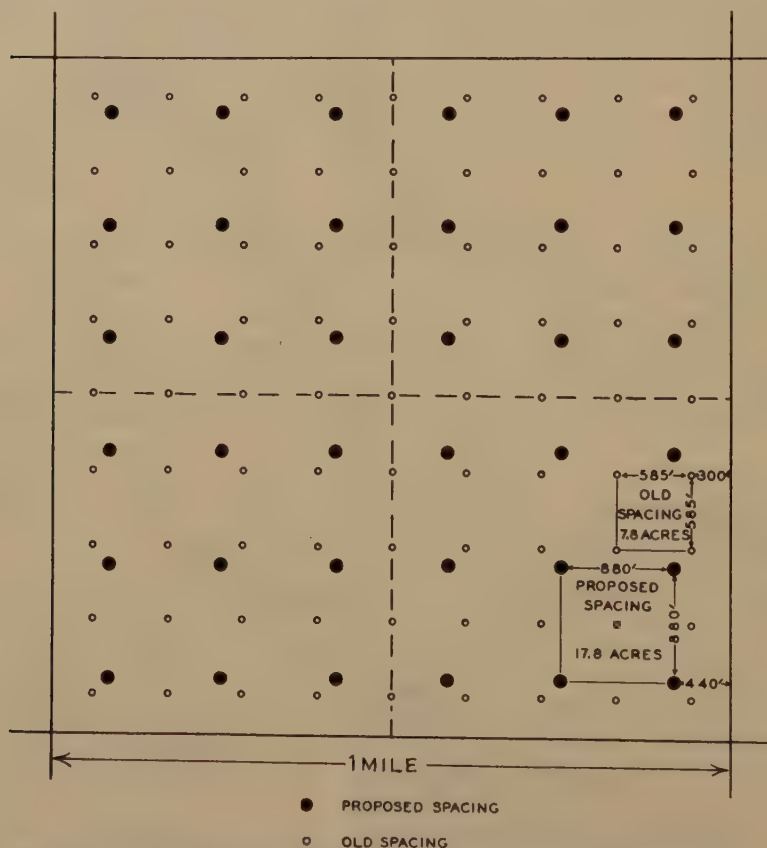


FIG. 2.—IDEAL SECTION SHOWING SURFACE LOCATIONS FOR THE OLD POOL.

quarter section, were established. The first wells to be drilled under this plan are called "primary wells," and are located in the center of each quarter section as shown on Fig. 3. The plan contemplates the drilling of the primary wells first on each operating unit, which will give $\frac{1}{2}$ mile

spacing between the first wells. Such wide spacing in an even pattern over the productive portions of the structure automatically eliminates unnecessary competition, practically all drainage considerations, and other troublesome factors involved in the completion of the early wells in a field if located in the corner of the section or lease (Fig. 2).

After the primary wells are completed on an operating unit of 160 acres, the "secondary wells" may be drilled. These wells are located due

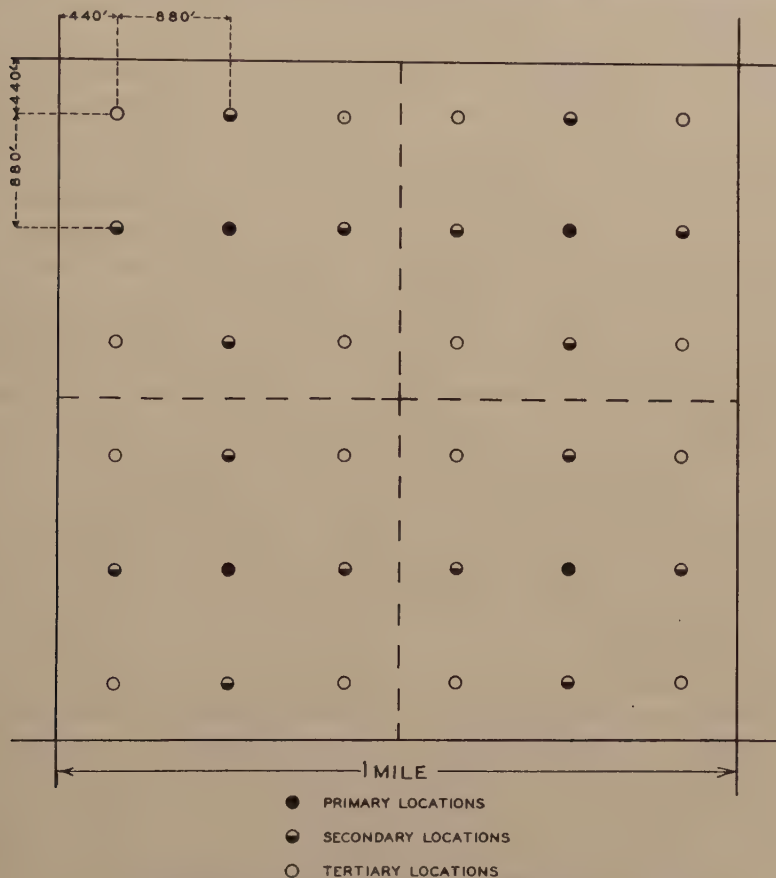


FIG. 3.—IDEAL SECTION SHOWING SUBSURFACE LOCATIONS FOR THE POOL.

north and south, or due east and west of the primary wells. It is obvious from Fig. 3 that the only offset required by the owners of the adjacent operating unit will be one secondary well on their own unit, in lieu of the three offsets required if a well were completed in the corner of the section or lease.

After all primary and secondary wells are completed the operator may proceed with the drilling of the "tertiary wells," which are in the four corners of the operating unit.

These wells are to be located 440 ft. from the quarter-section lines, with 880 ft. between the wells. Such spacing gives a theoretical drainage area of 17.8 acres. The present spacing in the Buena Vista Hills is based on a 7.8 acres spacing as shown on Fig. 2. If subsequent developments prove that closer spacing of wells is necessary, by agreement of the signatory parties holding 80 per cent of the acreage, the spacing program may be modified.

The above drilling program and spacing of wells will be found entirely satisfactory for operating units that are on the higher portions of the structure. It is possible that certain of the operating units are so located near the edge of the field that the primary location would not be productive of oil if drilled. In that event, the operator may select a secondary location to be drilled in lieu of the primary location, providing that the operators of 80 per cent of the acreage agree that the primary location is outside of the productive limits. In the event that all secondary locations on the operating unit are considered unproductive, by the same procedure a tertiary location may be selected for the first well.

The plan also provides that, notwithstanding the requirements of this drilling program, an operator may drill any and all wells on the exterior boundaries of the pool that may become necessary to prevent drainage of his operating unit by operations on lands not subject to the cooperative plan.

The drilling program described applies with equal force to each zone discovered to be productive within the limits of the pool. If two separate and distinct zones are located, each operating unit may have 18 wells drilled thereon, unless further agreements are made to permit of deepening certain of the first nine wells, or other equitable procedure adopted.

It is quite clearly stated in the cooperative plan itself that nothing therein obligates any operator of an operating unit to drill any well or wells within the pool. Terms of the several leases and good business judgment are considered sufficient to govern the drilling of wells on each operating unit to protect the various interests involved.

UNIFORM PRODUCING PRACTICES

In order that no operating unit may be disproportionately drained of its oil and gas content by operations on adjacent operating units, the plan provides that by agreement of operators holding 80 per cent of the acreage within the pool uniform producing practices shall be adopted, which will be binding upon all of the signatory parties. This section of the cooperative plan is intended to prevent one operator from producing wells with an excessive gas-oil ratio, or at such a rate that one may recover more than his fair share of the oil and gas content lying thereunder. It is

also aimed to control the producing methods at each well in order that the maximum ultimate recovery may be obtained by each unit.

To assist all operators in the proper solution of practices or problems arising from the operation of the plan, if the operators of 80 per cent of the acreage within the pool so request, an engineer or engineering staff may be employed to study such problems and report the findings to the operators for their information and guidance. The cost of such engineering advice and reports will be met by assessment of all operators in proportion to their respective oil production from the pool for the month preceding that in which such report is rendered. After consideration of the report by the operators' committee, and further discussion by all operators concerned, the solution of the problem by vote of the operators of 80 per cent of the acreage of the pool shall be binding upon all signatory parties.

The cooperative plan provides that the vote of operators controlling 80 per cent of the acreage shall govern all drilling and producing practices in the pool, and that the cost of any engineering studies or reports shall be defrayed by an assessment on the basis of the previous month's production rather than on an acreage basis.

UNITIZATION OF OPERATING UNITS

The spacing of the wells, and the order of drilling the wells, as shown on Fig. 3, was based on the assumption that each 160 acres, or one-quarter section, constituted an operating unit under one ownership or management, and also for the reason that by this spacing the fewest number of wells fell on property lines, and that the fewest number of subunit plans would be required. It was considered that 160 acres was the smallest practical operating unit. Over a dozen of the quarter sections of land contain divided ownerships (Fig. 1).

The plan for cooperative development provides that, where the ownerships are divided and before any wells are drilled to the pool, which underlies the present productive zones of the "old pool," each of these quarter sections will be unitized. Unit plans for such of the operating units as are held in divided ownerships under a Government oil and gas lease have been consummated. Where only fee holdings are involved, it is understood that unit plans are pending, and will, no doubt, be adopted before any deep drilling is undertaken.

These unit plans for operating units of one-quarter section in area have the following common provisions. They provide that one of the two parties be the Operator of all line wells drilled on the common property line. The second party is called the Associate. Wells drilled on the common property line are called Joint Wells. Where no wells fall on the common property line, one company is appointed the Operator to drill and produce all of the wells on the unit. With this exception and for other than Joint Wells on the common property line, each operator

may drill and produce his own wells on the unit. The Operator is required to submit an estimate of the cost of drilling the Joint Wells, and if this figure is not satisfactory to the Associate, the latter may submit an estimate of the drilling cost. If a mutually satisfactory agreement as to costs cannot be adopted by the two parties, bids may be received from drilling contractors, and a contract awarded. These subunit plans contain sufficient provisions to guarantee that the Joint Wells will be drilled at a mutually satisfactory cost. After completion of the Joint Wells the Operator, for a stated period of time, usually for five years, will continue to operate the well. The direct cost of drilling and operation of these Joint Wells is prorated between the two parties, plus an allowance to the Operator of a definite sum per month to cover superintendence, geological and engineering expenses, and other such items ordinarily included in "overhead." After the expiration of the stated period, the Associate may take over the operation of the well, and thereafter the two parties will alternate in operating the Joint Wells. The drilling and production costs of the Joint Wells, and the petroleum products therefrom, are shared equally by the two parties, if the acreage involved is owned equally, otherwise on an acreage basis. For the purpose of computing the Government oil royalties where they involve the number of wells producing on the lease, such Joint Wells located on the common property line are counted as one-half a well for each lessee.

Space does not permit the setting forth of the other details of each unit plan. In general, the plans are so drawn that the wells are drilled and produced by mutual consent at a cost satisfactory to each party. The agreements between the two parties may be changed at any time, providing the requirements of the cooperative development plan for the field as a whole are not violated.

PROTECTION AGAINST DRAINAGE BY OUTSIDE INTERESTS

In any plan for cooperative development of an oil-bearing structure a real effort is made to include within the area subject to the plan all possible productive parcels of land. Also, all owners of lands within the probable productive area are urged to sign the agreement. However, it frequently happens that all of the productive acreage is not included within the area of the unit plan, or all owners of the productive acreage do not deem it advisable to join in the plan.

When this condition exists, there is always the threat of drainage of those operating units within the defined area by operations on adjacent lands which are not conducted in accordance with the provisions of the cooperative plan.

To provide for this contingency, there is a provision in the cooperative development plan for this field which permits any operator to drill such wells as may be necessary at any time and in any place in order to prevent

drainage of the operating unit which he controls by operations on lands adjacent thereto but not subject to the requirements of the cooperative plan.

Inasmuch as the operators of over 99 per cent of the acreage within the area of the field have adopted the cooperative development plan, this contingency is not as alarming as it would first appear.

MODIFICATION OF PLAN BY CONSENT OF OPERATORS

As development of the field progresses, it is conceivable that engineering practices or economic conditions may warrant changes in the provisions of the cooperative development plan. Such changes may be adopted by the consent of the operators of 80 per cent of the area subject to the plan, and when so adopted are binding upon all of the signatory parties.

CURTAILMENT OF PRODUCTION

The cooperative development plan provides for the restrictions of the quantity and rate of production of oil, gas and gasoline from lands within the area by such method as may be voluntarily assumed by the operators of 80 per cent or more of the area. Thus, curtailment of oil production, and incidentally of gas, through affirmative action by the operators of 80 per cent of the area will become binding upon all of the signatory parties.

CONSENT OF ROYALTY OWNERS

In any oil field it is common to find that the operators of certain parcels of land have supplementary agreements with royalty owners, excepting from this group the United States as lessor, which agreements conflict with the provisions of the cooperative development plan. In order to modify these prior agreements, it was necessary to obtain the consent of the royalty owners to the execution of the plan by the operators and to agree that the development of the area in the manner set forth in the plan shall be considered as full performance of all obligations for development and operation of certain parcels formerly required under the original agreement with the royalty owners. These consents of royalty owners have been obtained in practically all instances.

The modification of the original royalty owner agreements, as set forth above, eliminates any conflict between lease requirements, royalty owner agreements, intracompany desires and needs, and curtailment of production. The several provisions of these various factors are subordinated to the cooperative development plan, the workings of which are carried out by agreement of the operators of 80 per cent of the area subject to the plan.

PLAN-AGREEMENT BETWEEN UNITED STATES AND ITS LESSEES

Approximately 37 per cent of the area subject to the cooperative development plan for this field is controlled by the United States. Except the 3 per cent of the area owned by the U. S. Navy and not leased, 34 per cent is under lease to various operators. These leases from the Navy Department and from the Department of the Interior were granted about 1922 for a period of 20 years, with certain provisions for renewal for successive 10-year periods.

Statutory authority contained in the Acts of Congress approved March 4, 1931, and Aug. 21, 1935, which Acts amended the Oil and Gas Leasing Act of Feb. 25, 1920, permitted the Secretaries of the Navy and Interior to enter into unit plans involving the cooperative development of an oil and gas-bearing structure.

These Acts permitted the respective Secretaries to modify the drilling and producing requirements, the terms, and the royalty provisions of the leases heretofore issued under the Act of Feb. 25, 1920.

After the cooperative development plan for the Buena Vista Hills field had been formulated, it was necessary to modify the provisions of the existing Federal leases to conform to the requirements of the basis plan. Under the plan-agreement all leases from the United States are extended for the life of the field, providing that the lands under lease continue to be subject to the plan. The royalty scales for oil, gas and gasoline produced and sold from the "old pool" remain unchanged. For production from the new pool new royalty scales have been adopted, which in most cases are somewhat lower than those in effect for the old pool for wells below approximately 1700 bbl. per day in size. For larger wells the new scale is slightly higher. Space does not permit a detailed analysis of the new royalty scales.

The agreement between the United States and its lessees provides that the Operating Regulations approved July 1, 1926, as amended prior to July 1, 1935, shall be effective for these leases in lieu of all other operating regulations promulgated by the Government.

The Secretary of the Department having jurisdiction over the lands of the United States is vested with the authority to control the rate of development and of production from these lands in order that the Area may enjoy its fair and proper share of the allowable production for the State of California under any system of voluntary curtailment generally recognized by the operators in this field, or by any system authorized by law.

The United States continues to have the right to take its royalties in kind whenever it may so elect.

The lessees of the United States agree to protect the Government lands from loss of royalty through drainage within and without the

exterior boundaries of the Area by either drilling and producing the necessary offset wells, or by paying compensatory royalty in lieu thereof.

The plan-agreement with the United States provides that if for any reason it is terminated with respect to any Government lease the original terms and conditions, including rents and royalties, of the lease shall become effective. If termination occurs prior to the date of expiration of the lease, it shall be renewed as provided in Section 17 of the Act of Feb. 25, 1920. If any lands leased from the United States are excluded from the pool, as provided for in the cooperative development plan, then such lands revert to the status of the lands in the old pool.

The agreement provides that the United States will not lease or operate any lands it may own, except subject to the terms and conditions of the plan-agreement.

Provision is made in the plan-agreement to amplify, change, or modify the terms of the agreement with the written consent of the operators of 80 per cent of the area of the leases included in the plan-agreement, with the written approval of the respective secretaries.

GOVERNMENTAL APPROVAL

The cooperative plan of development for this field as finally drafted is dated Oct. 1, 1935. The several agreements between the lessees of certain operating units of one-quarter section each, where the ownership was divided, were executed early in 1936. On April 30, 1936, the Oil and Gas Supervisor for the State of California, as required by state law, approved the plan-agreement for cooperative development, and determined that it was in the interest of the protection of oil and gas from unreasonable waste that the plan-agreement be entered into by the signatory parties thereto.

On July 6, 1936, the President of the United States consented to the execution of the plan-agreement by the Secretary of the Navy. Under present laws this consent was required for any lands within the Naval Petroleum Reserves. On July 9, 1936, the plan-agreement was executed on behalf of the United States by the Secretaries of the Navy and of the Interior, thus completing the adoption of the plan by all interested parties.

FUTURE POSSIBILITIES UNDER THE COOPERATIVE PLAN

The upper sands of the old pool are now well depleted. Sufficient data on the gas repressuring and recycling programs being carried on there now are available to indicate that these upper sands may be readily repressured with dry gas, or used as storage space for volumes of gas above market demands. From an engineering point of view an ideal situation exists whereby substantial oil production with high gas pressures may be obtained from the deeper zones during the summer months of increased market demands for oil, while the high-pressure gas, for which

there is but a small summer market, after being treated for its gasoline content may be stored in the depleted upper oil measures. During the winter months, when the gas market is able to absorb larger volumes of gas, such stored gas may be withdrawn from the upper zone, treated for its gasoline content, and sold to the public utilities.

The elimination of unnecessary competition and the fostering of cooperative effort by the plan indicate that there is every reason to believe that the deeper zones in this field will be developed in the most economical manner and that duplication of facilities will be kept to the minimum.

Review of Developments at Kettleman Hills

By R. E. COLLOM* AND C. P. WATSON,† MEMBER A.I.M.E.

(Los Angeles Meeting, October, 1936)

VARIOUS chapters already written in the history of development of the North Dome of Kettleman Hills are monotonously identical in the one underlying theme of conservation of oil and gas. Discovered on Oct. 4, 1928, by Milham Exploration Co. with its wildcat Elliot No. 1, the field has been subjected to practically every modern form of production restraint in the name of conservation. The record thus far developed shows that conservation was had for a time, at a price; and that unitization must be blessed by single ownership or 100 per cent participation to be effective. In fact, incomplete unitization places a heavy handicap upon its participants in the competitive development that follows.

SHUT-IN AGREEMENT OF JULY 25, 1929

Not long after discovery at Kettleman but after the Continental Oil Co. and the Standard Oil Co. had completed several producing wells in the discovery group, came the so-called Shut-in Agreement negotiated at the instance of the Department of the Interior. This agreement became effective July 25, 1929. The fundamental purpose of the agreement was to prevent bringing on production of some 30 wells then being drilled and forestall a flood of Kettleman oil on the market. A cooperative scheme was developed whereby wells in the discovery group would continue to produce. Two of them could not be shut in. Drilling wells would be completed to a water shutoff in top of Temblor and operations suspended. Producing wells would contribute the value of 10 to 25 per cent of their production to the owners of suspended qualifying wells. The percentage rate of drainage contribution was left to a committee or umpire. Some acreage was not placed under the agreement. This same acreage later did not come into the Kettleman Unit Agreement. Several wells on this acreage did not contribute to the drainage fund.

The total amount of oil produced during the 17 months of the shut-in agreement, by Milham, Continental and Standard from wells in the discovery group, was 5,297,262.22 bbl. The total amount paid out in "drainage" contributions was \$2,046,048.18, representing sales value of 1,266,044.06 bbl. of oil.

Manuscript received at the office of the Institute Oct. 13, 1936.

* Vice President, Continental Oil Co., Los Angeles, Calif.

† Vice President, Seaboard Oil Corporation, Los Angeles, Calif.

The shut-in agreement was unquestionably effective. Much oil was kept off the market and "drainage" was compensated liberally, principally by Milham Exploration Co. and Continental Oil Co. Standard Oil Co. had about 50 per cent of the qualifying wells scattered around the field, participation of which in the fund about offset the amount paid out by Standard Oil Co. from its producing wells. The principal issues of that episode were production control and drainage. They continue to be the active issues at Kettleman.

KETTLEMAN UNITIZATION

Paragraph 3 on page 4 of the agreement of July 25, 1929, reads as follows:

In line with the Government's policy of oil conservation, to which this agreement contributes, the parties interested in the Kettleman Hills field undertake, by the appointment of a representative committee or by other means, to consider a plan of unit development or other cooperative method of developing this great structure with a maximum of production and utilization at a minimum of operating cost; such committee to report its progress from time to time to the Secretary of the Interior, and when deemed opportune, the Secretary will propose the necessary legislation enabling the Government's participation in the proposed cooperative plan, by authorizing both the necessary acreage involved and the substitution of a fixed and definite share in the output in lieu of the existing different rates of royalty for primary and secondary leases.

On Feb. 12, 1930, a meeting of the operators of the North Dome of Kettleman Hills was called, at which this portion of the shut-in agreement of July 25, 1929, was read. The operators then formally appointed a committee for the purpose of "studying all plans on the orderly development and production operations of the North Dome at Kettleman Hills." This became the Kettleman North Dome Committee, which drew up the unit agreement of Kettleman North Dome Association.

Two general plans were first considered; a unit plan and a "cooperative" plan. Opinion rapidly crystallized in favor of a unit plan.

Kettleman Hills, a long anticlinal structure, lies across the boundary line between Fresno and Kings counties on the west side of the San Joaquin Valley. About 15 miles long and two miles wide, the field encloses about 16,500 acres of participating oil and gas lands. Of this acreage approximately 50 per cent is unitized. The division of control is as follows:

	Acres	Per Cent
Kettleman North Dome Association.....	8,210	49.7274
Outside fee acreage, not including Standard fee.....	540	3.2708
Total Standard Oil fee.....	7,760	47.0018
Totals.....	16,510	100.0000

After 15 months of deliberation, the unit agreement of Kettleman North Dome Association was executed as of Jan. 31, 1931. In order to give it some semblance of effectiveness as a unitization project, it was necessary to work out some cooperative balancing arrangement with Standard Oil Company of California. After a delay of several years such an arrangement is in effect. At one time also Kettleman North Dome Association had under consideration the purchase or acquisition of control of acreage in sections 29, 35 and 36. This appeared necessary in order to prevent Kettleman being thrown into a competitive development situation. Many obstacles prevented this acquisition.

The Articles of Incorporation of Kettleman North Dome Association set forth the *purposes* of unitization as follows:

The purposes of the corporation shall be to provide without profit to the corporation for the unified development and production of oil, gas and other hydrocarbons from the North Dome of the Kettleman Hills, Fresno and Kings Counties, California, under agreement between the Secretary of the Interior of the United States and various owners of lands and/or persons operating or having right to develop and operate lands for production of oil, gas and other hydrocarbons therefrom within said North Dome of the Kettleman Hills, with the aim that ultimately each and every member shall have received his just share of products derived or revenues received from production and shall likewise have paid his just share of the expenses of winning said products and revenues, and to the end that there may be an orderly development of said North Dome Field so that there be ultimately recovered the greatest amount of oil, gas and other hydrocarbons with the least possible waste of such natural resources; to extract natural gasoline from gas produced by the corporation from the unified area, either in plants operated by it or under contract with others; to distribute oil, natural gasoline, gas and other hydrocarbons produced among its members in kind or on their order, and/or at the request of any member to sell any or all of such products for said member.

All major companies in California were interested in seeing some form of unitization put into effect in California. Several of them undoubtedly mistook production control for unitization. They were anxious to see unitization for the other fellow. Some of the smaller interests feared that acceptance of unitization would definitely provide an effective throttle to be applied to the potential production of this field while other fields in the state enjoyed a greater proportionate share of the state's allowable. That this possibility was recognized in other quarters is shown by the following quotation from a letter written to Mr. William Reinhardt, Chairman of Kettleman North Dome Committee, by Dr. George Otis Smith, Director of the U. S. Geological Survey, on July 8, 1930. The occasion for the letter was the passage of unit operation amendments to the general Land Leasing Law:

As unit operation touches upon limitation of production, reference of the matter to the Department of Justice was necessary. First of all, there appeared to be little in common between our two views of the subject: desire for efficiency, economy, and

conservation on the one hand; fear of monopoly, restraint of trade, and a higher price for gasoline on the other.

All of the necessary safeguards were placed in the unit agreement so as to prevent monopoly; to insure Kettleman a proper proportion of the state's production; to insure maximum production at minimum cost and to divide recovery of products on an acreage basis.

There was just one thing lacking—part of the acreage was not unitized. Government, in its anxiety to perfect unitization, forced its lessees into a unit plan but failed or was unable to apply the necessary

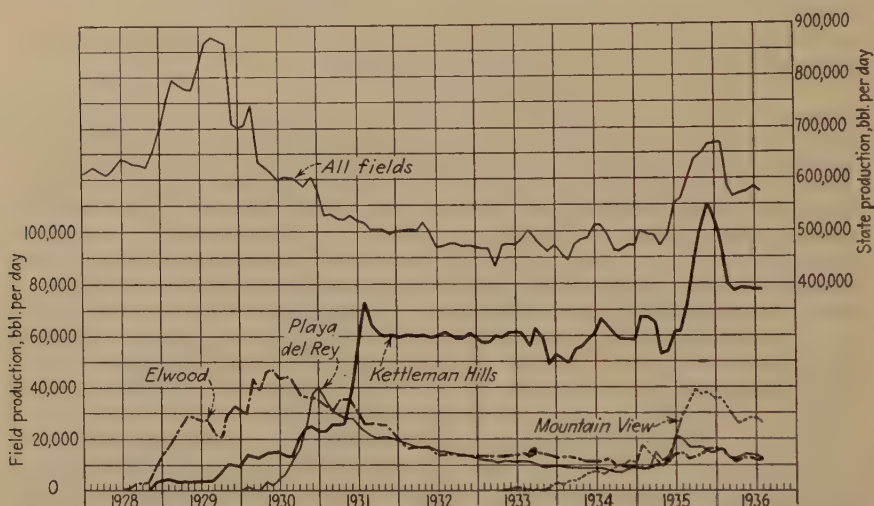


FIG. 1.—DAILY PRODUCTION OF NORTH DOME OF KETTLEMAN HILLS, ELWOOD, PLAYA DEL REY, MT. VIEW AND OTHER CALIFORNIA FIELDS.

pressure to bring in the fee landowners. In a practical sense therefore there is no unit operation at Kettleman. The North Dome of Kettleman Hills is being developed competitively and wastefully in spite of the efforts of the Kettleman North Dome Association. Less than 5 per cent of the participating acreage of Kettleman Hills has set the pace for development and has dictated the internal allocation of oil production. For four years since unitization, Kettleman, representing one-third of the reserves of the state and one-fifth of the potential, has produced on an average of 60,000 bbl. per day (Fig. 1).

GAS DOMINATION

It may not be entirely accurate to place all the responsibility for setting the pace of production on the nonunitized operators. Kettleman is a major source of supply of gas for the utilities. Although the field has produced 137,830,931 bbl. of oil to Sept. 1, 1936, some interests still conveniently insist that it is a gas field. The rate of gas withdrawal has

been an important factor in the manner of producing the field. It would be most fortuitous if the pace of production set by demands of the gas utilities were proper and efficient.

Of the state's production, Kettleman North Dome currently produces daily 78,000 bbl. (13.6 per cent) of the oil and 411,653 gal. (25.75 per cent) of the natural gasoline. Of the gas delivered to utilities, Kettleman is furnishing 200,000 M. cu. ft. daily, or 41.6 per cent.

In order to appreciate the importance of gas in the Kettleman situation it should be borne in mind that a gas cap originally occupied a restricted elliptical central portion of the field. From the upper part of the Temblor formation within the gas cap, wells produce a 60° gravity oil at ratios as high as 100,000 cu. ft. per barrel of oil. From the lower part of the Temblor within the gas cap, and annularly outside the gas cap, is a so-called black-oil belt with wells that before expansion of the gas cap produced oil as low as 35° gravity with gas-oil ratios less than 1000 cu. ft. per barrel.

It is apparent therefore that under complete unit operation, and even under competitive operation, some considerable variation is possible as to the amount of gas produced per barrel of oil.

A free and open outlet was maintained for gas whereas a severely restricted outlet was set upon oil. This condition placed a premium on high gas-oil ratios and dissipation of the gas cap.

The following comments on this situation were made by the Petroleum Administrative Board in its report and recommendations relative to appeal of Superior Oil Co. and Amerada Petroleum Corporation from the general method of intrafield allocations in effect at Kettleman Hills North Dome field since May 1, 1934:

A survey of the record of this case and other official sources of information shows that the production of hydrocarbons from the Kettleman Hills North Dome field from Oct. 5, 1928, to Dec. 31, 1934, has been as shown in the accompanying table.

	Crude Oil, Total Barrels Daily Average	Natural Gas, Total M. Cu. Ft. Daily Average	Gas-oil Ratio	Natural Gasoline, Total Gallons Daily Average
1928	2,377-84 days	36,000 est.	15.0	
1929	5,355	114,844	21.4	74,490
1930	16,946	409,258	24.2	428,531
1931	48,043	377,947	7.9	465,979
1932	59,970	270,807	4.5	372,021
1933	58,840	285,907	4.9	356,763
1934	58,253	319,410	5.5	411,113

These figures indicate clearly that the North Dome field is to be noted principally for its gas production rather than its oil. The record shows no dispute of the conclusions of the Advisory Board that "the money value of the energy stored in the gas is worth many times more than the market value of the gas as fuel."

It is to be inferred then that North Dome operators are in agreement on this fundamental tenet but it is apparent from the foregoing figures that the gas cost of producing oil is either excessive or that the revenues received from the sale of gas exceeded its value for the production of oil. Otherwise it would be difficult to justify the preponderant production of gas to date from a field with characteristics indicating that the most efficient recovery of oil can be obtained only by the complete utilization of natural gas as a propulsive and lifting agent. The conservation of oil in fields of the North Dome type very definitely depends upon the conservation of the associated gas.*

Production data quoted above are brought to date as follows:

	Crude Oil, Bbl. per Day	Natural Gas, Total M. Cu. Ft. Daily Average	Gas-oil Ratio, M. Cu. Ft. per Bbl.	Natural Gasoline, Daily Average, Gal.
1935	75,534	332,712	4.4	422,122
1936 Sept. 1	80,612	266,908	3.3	428,522

Fig. 2 shows the sales of gas from Kettleman Hills from January 1933 to date as compared with total utilization in the state.

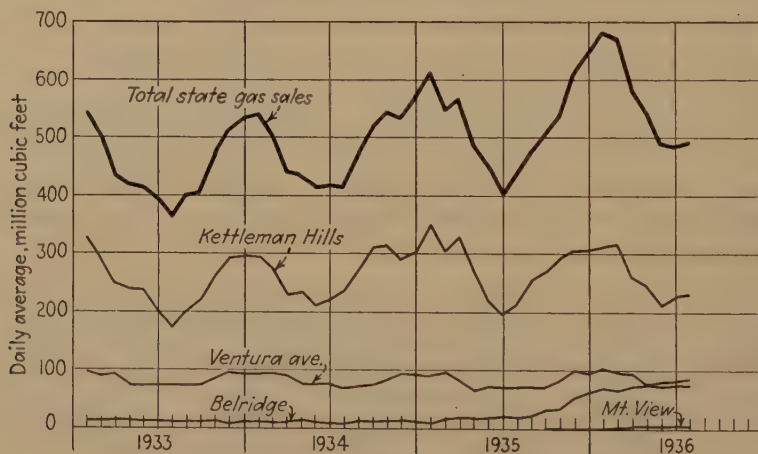


FIG. 2.—DAILY AVERAGE DRY GAS SALES, CALIFORNIA.

Gas sales in Kettleman are divided among various operators approximately as shown in Table 1.

COMPETITIVE DEVELOPMENT STARTS

With the termination of the shut-in agreement and start of operations under Kettleman North Dome Association, as of April 1, 1931, competitive development and production of the North Dome got into full swing. Until that time the records show the following:

* Report and Recommendations Petroleum Administrative Board, 11 (March 25, 1935).

1. During the year 1930 the elements of competitive development were gathering strength through completion of wells by Petroleum Securities, Associated Oil Co. and Superior Oil Co., which were not part of the so-called shut-in agreement.

2. In the latter part of 1930, Superior Oil Co., with its Huffman 1, was producing almost half the oil coming from the eight wells then producing in the field. It was producing about $\frac{1}{10}$ of the gas.

TABLE 1.—*Dry Gas Sales, July 1936, Kettleman Hills*

	M. Cu. Ft.	Per Cent	M. Cu. Ft.	Per Cent
K.N.D.A.....	2,556,922 ^a	38.5	1,906,229 ^b	28.7
Standard.....	2,779,075	41.9	3,429,768	51.7
Others.....	1,300,000(Est.)	19.6	1,300,000(Est.)	19.6
	6,635,997	100.0	6,635,997	100.0

^a Includes field delivery of 650,693 M. cu. ft. by Kettleman North Dome Association to Standard.

^b Excludes field delivery of 650,693 M. cu. ft. by Kettleman North Dome Association to Standard.

3. Gas to the amount of 311,073 M. cu. ft. was being blown to the air during November, 1930.

4. Of the 480,000 M. cu. ft. of gas available, only 170,000 M. cu. ft. was being utilized.

5. Of the 170,000 M. cu. ft. utilized, Standard Oil Co. had an outlet for 104,000.

6. Two wells, Milham and Continental, could not be shut in and were blowing 125,000 M. cu. ft. daily.

7. All wells except Superior's Huffman were producing with high gas-oil ratios varying from 25 to 40 M. cu. ft. per barrel of oil. Superior's Huffman gas-oil ratio was about 3 M. cu. ft. per barrel of oil.

8. Six months before the shut-in agreement was terminated three wells, not in the agreement, were producing more than half the oil in the field and were not contributing to the drainage fund.

Waste of Gas.—The California gas law, based upon the premise that the blowing of gas to the air is prima facie evidence of waste, and ostensibly framed to prevent the waste of gas but actually conceived and sometimes invoked to control the production of oil, was used as the basis of an action by the people of the State of California against an oil company to prevent waste of gas. Issuance of temporary injunction hinged largely upon such factors as optimum gas-oil ratios and the proper or appropriate definition of waste. Waste was variously interpreted to be underground waste, energy waste, economic waste, or perhaps just physical waste, with the result that court, lawyers, engineers and experts were more or less perplexed by the confusion into which their own arguments and inventive-

ness had brought them. Temporary injunctions, which caused no appreciable pause to the competitive forces that were gaining momentum during the period that the unit plan was being formulated, were issued. The case hung in the court for several years and was finally taken off the calendar.

It is noteworthy that the same group of major companies that so strongly advocated unitization and were currently contributing to the construction of the unit plan, although finally refusing to place their acreage in the plan, were on the side of the state in the gas suits. The gas suits failed to effect equitable control of oil production at Kettleman. At the end of 1930 the field's production was about 25,000 bbl. of oil per day and 480 million cubic feet of gas. By Aug. 1, 1931, the production of both Kettleman North Dome Association, Standard Oil Co. and Superior Oil Co. was such that some form of curtailment appeared necessary.

PRODUCTION CURTAILMENT AND PRORATION

In approaching the subject of production curtailment and proration, it should be borne in mind that there was not a single operator in Kettleman Hills that had not participated fully in the discussions and voting regarding the various articles and terms of the Kettleman Unit Agreement. Until the last few days of the 15 months of negotiation it was assumed by those most active in cooperation with the Secretary of the Interior that the Unit Agreement would be "100 per cent effective."

In the early stages of discussion of the Unit Agreement several operators were strongly in favor of weighting acreage, according to position on structure and therefore variation in productivity, for participation. This idea was discarded and participation was to be determined on a flat acreage basis. Secretary Ray Lyman Wilbur, in his telegram of March 19, 1930, stressed the factor of the acreage basis of participation as follows:

I appreciate that the proposed plans are rational because they substitute for the expensive and wasteful drilling of offset wells the equitable sharing by the undrilled acreage in the production from the area as a whole.

That was the basis of equitable division of production. In fact, that is the present internal basis of distribution in Kenda. The outside operators at Kettleman having talked and voted and exerted their best efforts to get the unit agreement in such shape as would best handicap operators thereunder in any competitive development scheme proceeded to operate competitively and refused to accept proration on an acreage basis. They insisted that the small operator is inherently entitled to the lion's share; that the most productive acreage is entitled to be weighted against lesser productive acreage and that unless any given subdivision of acreage is drilled and occupied by a producing well it should not be

entitled to consideration in proration. No one should expect that outside operators are bound to conform to the Unit Agreement but the conclusions of both Advisory Board and Petroleum Administrative Board were that some recognition should be given to the principle of acreage participation.

The method of proration therefore became the prime matter of controversy in Kettleman. It led to extended hearings before the so-called Advisory Board during March and April, 1934; appeals of the decisions of that Board and subsequent hearings before the Petroleum Administrative Board in December 1934. The 705 mimeographed pages of transcript taken before the technical Advisory Board and the 52-page mimeographed report of the Petroleum Administrative Board contain a mass of facts, technical material and considerable misinformation regarding Kettleman Hills.

After all these hearings and labor of engineers, lawyers, and laymen, followed by recommendations and formulas for equitable internal allocation of production at Kettleman Hills, the same gross inequities making for general losses, as to ultimate recovery, to all remain unchanged.

The history of proration from its beginning down to hearings before the "Advisory Board appointed by the Central Committee" in 1934, is briefly given below by quoting from the testimony of William Reinhardt, manager of Kettleman North Dome Association (see pp. 41 to 46, inclusive, Part I of transcript of said hearings):

In August, 1931, an allotment of 60,000 barrels per day was made to the field. Of this amount the outside companies were allotted 15,000 barrels per day, or 25 per cent of the total allotment, and the Standard Oil Company and the Kettleman North Dome Association jointly 45,000 barrels a day, or 75 per cent. This allotment, and the same basis of distribution, continued to October, 1932, when the field allowable was reduced by 10 per cent. The same percentage of distribution, however, continued to and including December, 1932. In the months of January to April, 1933, inclusive, the field allowable varied from 55,000 barrels a day to 63,000 barrels a day, and while there were some variations, the percentage distribution remained substantially as in the previous 17 months.

In May, 1933, the outside companies' allotment was set at 20 per cent of the total, which percentage continued during the months of June, July, and August.

On the adoption of the Petroleum Code and the formation of the Central Committee of California Oil Producers in September, 1933, the allowables were calculated on the basis of a formula which was used during that month for the whole state. This formula gave the outside companies 17.4 per cent of the total allotment to the field. For the month of November, the breakdown was again revised, giving the outside companies 20.6 per cent.

In December, 1933, the Central Committee suggested that again the Field Committee get together and attempt to arrive at a more permanent procedure for the breakdown. They agreed for the month of December on a schedule which gave the outside operators 18.5 per cent of the total. This schedule was continued for the month of January, 1934. For the month of February, 1934, the Umpire on his own initiative raised the outside acreage percentage to 20 per cent.

Shortly after the Kettleman North Dome Association took over the operation of the properties of the member companies in April, 1931, meetings of the various operating companies in the field were held to attempt to arrive at a method whereby there would be equitable distribution of the allowable in the field. There had been very little restraint on production up to this time, except that which was caused by the limitations of outlet.

After a long series of discussions extending up to approximately August 1st, a temporary agreement was reached whereby the outside operators would receive 25 per cent of the field's allowable and the Standard Oil Company and the Association 75 per cent jointly. This breakdown was vigorously protested by both the Association and the Standard Oil Company, and was only accepted when they were advised in no uncertain terms that the outside operators would agree to no less. The outside operators simply stipulated individually what the absolute minimum was that they would accept. The accumulation of these minimum stipulations amounted to the 15,000 barrels a day which was previously mentioned.

Very little beneficial result was secured from these efforts. While the Association and the Standard Oil Company during all this period had adhered strictly to the principle that acreage distribution is the only equitable and fair method for this field, they offered several compromise plans in the hope of arriving at a method which would be acceptable to all, even temporarily, thereby affording some relief under these intolerable conditions. These offers of compromise were, however, always refused by the outside operators.

At a meeting held early in December an arbitrary breakdown for the month of December was agreed upon. A subcommittee of the Field Committee was then appointed to attempt to draw up a plan which would be acceptable. This committee also failed to reach an agreement. In January, 1934, at another meeting of the Field Committee, another compromise plan was offered by the Standard Oil Company and the Association members. This plan also having failed to get the support of the outside operators, the matter was referred to the Central Committee for action. The Central Committee, hesitating to act on a matter which involved so many opposed ideas, passed a motion to appoint a Board of Arbitrators to develop a plan; this compromise plan which had been offered providing, among other stipulations, for arbitration to take care of controversies which might develop in the functioning of the plan.

This motion named one of the members of the Board of Arbitration in the person of George W. Holland of the Geological Survey, stipulating that one member should be selected by the Standard Oil Company and Association group and the other by the outside operators. The outside operators refused to make a selection or leave the matter to this Board of Arbitration. The matter having gone back to the Central Committee, your Board was selected.*

The Kettleman North Dome Association has always maintained and still maintains that the only fair and equitable method for the distribution of the field's allowable is on an acreage basis. All of the deferment of development in this field has this principle as its foundation. The very prosperous conditions which have prevailed in this field for the outside operators have only been possible because of the willingness of the Standard Oil Company and the Kettleman North Dome Association to defer their development operations.

It has often been said in the course of discussions in Field Committees, and otherwise, that this deferment, both on the part of the Standard Oil Company and the

* This Board was composed of R. P. McLaughlin, W. N. Lacey and Walker S. Clute.

Association, was purely a matter of selfish interest. There may be something in that. I am not at all inclined to believe that any of us are apt to go very far against our own selfish interest in the development of our thoughts in matters of this type. However, the fact still remains that while that definitely may be charged to certain of the larger integrated companies who are involved in this picture, it certainly does not apply to many of the smaller operators, particularly those in the Association, and also it very definitely does hold that, even if that charge were true of all of the interests in the Association, the outside companies have quite definitely profited by this curtailment and its general effect of holding up the prices of crude in the field.

As will be shown by others, this deferment has resulted in enormous losses to both the Standard Oil Company and the Association, and can only be remedied by proper consideration being given to the presently undeveloped acreage of the two companies in the distribution of the field's allowable.

That drainage and inequitable distribution of production was and is taking place is shown by quoting testimony of N. A. Rousselot, of Seaboard Oil Corporation and a director of Kettleman North Dome Association, before the Advisory Board (pp. 105 and 106; Part I of transcript):

The allocation of production in Kettleman Hills has been divided among three major groups:

1. The Kettleman North Dome Association, which is a banding together of 14 companies, has under its control 8060 proven acres (participating).
 2. The Standard Oil Company, 7800 proven acres (participating).
 3. Outside companies, 510 proven acres (participating).
- This makes a total of 16,370 acres.

The Standard Oil Company and the Kettleman North Dome Association have balanced production between themselves on an acreage basis since the inception of the Kettleman Hills North Dome Association with very little difficulty.

To date, that is to March 1, 1934, the Kettleman North Dome Association has produced 29,908,416 barrels from 8,060 proven acres (participating), which is 49.2 per cent proven acres (participating) of the field.

The Standard Oil Company has produced 23,351,348 barrels from 7,800 proven acres (participating), which is 47.7 per cent of the field.

The outside companies have produced 19,319,340 barrels from 510 proven acres, (participating) which is 3.1 of the proven acreage (participating) of the field.

The Kettleman North Dome Association, on these figures has produced 41.21 per cent of the field production from 49.2 per cent of the proven acreage (participating).

The Standard Oil Company has produced 32.17 per cent from 47.7 per cent of proven acreage (participating).

The outside companies have produced 26.62 per cent from 3.1 per cent of the proven acreage (participating).

Just to illustrate what this means to one of the companies, the Milham Exploration Company, the discovery company of the field, which brought the field on to production in October of 1928, this company has 1710 proven acres (participating) within the field and they have received, both from the discovery well before the formation of the unit plan and the allocations allowed them by the Kettleman North Dome Association, the total of their production to March 1, 1934, has been 6,927,625 barrels. Whereas the Superior Oil Company, who has 160 proven acres, (participating) has produced 7,042,333 barrels being only 0.97 per cent of the field's proven acreage (participating).

The basis of allocation on Sept. 1, 1936, for a field allowable of 77,250 barrels was:

	Barrels	Per Cent of Allowable	Per Cent of Acreage
Kettleman North Dome Association.....	34,410	44.6	49.7274
Standard Oil Company.....	32,447	42.0	47.0018
Union Oil Company.....	4,000 5.2	13.4	3.2708
Superior Oil Company.....	4,000 5.2		
Others.....	2,393 3.0		
	77,250	100.	100.

DRAINAGE FOCI

These continued and extreme inequities in allocation of production coupled with the fact that Kettleman North Dome Association in distributing its allowables for maximum protection against drainage from outsiders in section 29 has set up some severe low-pressure areas characterized as drainage foci. In this connection the following is quoted from the report of Petroleum Administrative Board of March 25, 1935:

Individual well production records disclose some remarkable wells in the North Dome field. As of January 1, 1935, 31 wells had produced more than one million barrels of oil each with a total production of 68,048,917 barrels for the group. Outstanding among these wells is Huffman 1 of the Superior Oil Company which had produced approximately 5,798,505 barrels to January 1, 1935, and which undoubtedly will rank eventually as one of the most productive wells of the United States. The oil already produced by this well would fill to a depth of 38 feet a tank covering the entire 20 acres on which the well is located.

While it is probable that there are many fields where drainage areas show pressure gradients of greater magnitude than exist in the North Dome field, still the exhibits show conclusively that there are at least two notable drainage foci in that field. Drainage gradients to these foci and pressure differentials surrounding them are of such magnitude as to be very conducive to the migration of hydrocarbons toward those foci. One of the principal points of argument has to do with which properties should be the sites of the drainage foci.

It is impossible in theory and in fact to avoid a real drainage foci in continuously produced competitive fields but it is possible to reduce observed existing gradients by producing less in the area of lowest pressure and more in the peripheral areas of higher pressure, or by shutting the entire area in for a sufficient time to re-equalize sub-surface pressures over a wide area, during which time migration of fluids to the low pressure center will of course continue. It is probably possible to develop a concentric low pressure ring around a given area but in a competitive area close to edge-water an attempt to isolate one low pressure center by a still lower pressure belt around it would probably be both hazardous and inexpedient.

In the North Dome field it seems not improbable that the drainage gradients owe their genesis to the discovery wells of the focal areas and that present gradients though of wider range, may not be as great as in the past when production was even more concentrated than at present. Nor is it unlikely that drainage losses suffered by some properties in the past were much greater than those occurring now.

To make pressure gradients more equitable at this time and under present conditions would be a most difficult undertaking. It is not at all unlikely that *if the North Dome field were unit owned and operated* there might be low pressure foci just as significant as those now present. However, drainage to other properties and operators would not result.

The problem of preventing avoidable physical waste and of serving the public interest through the conservation of the petroleum resources in the field, in the Board's opinion, cannot be met solely through the promulgation of an allocation method or formula, because the solution of the problem involves, also, the adequate and systematic development and production of the field. If the field quota and its distribution within the field is maintained at its present level under present conditions, the factors which are conducive to waste will so continue and if the field quota were to be increased and the increase applied to existing wells, it appears that the conditions of production would be even more conducive to physical waste.

The situation in the Kettleman North Dome is complicated further by the existence of a "gas cap" area from which natural gas, accompanied by some production of "white" oil, is withdrawn in part for the purpose of furnishing a natural gas supply transported through pipe line to the San Francisco Bay and Los Angeles Basin regions where it is utilized for domestic, industrial, and commercial fuel purposes. Although it is recognized commonly that equity should be maintained between volumetric withdrawals of free gas and oil from a field, the Board feels that the excessive withdrawal of gas from the "gas cap" area or the production of oil with an excessive gas/oil ratio would result in a waste of reservoir energy and, in some instances, an irregular encroachment of water. The Board also is of the opinion that the excessive withdrawal of gas from any structure, even though the gas may move through pipe lines for purposes of serving fuel needs, is wasteful in its relationship to energy required for maximum oil recovery equally as much as if such excessive gas production were blown into the air.

HOW KETTLEMAN SHOULD HAVE BEEN DEVELOPED AND PRODUCED

Quoting again from the report of the Petroleum Administrative Board comes a suggestion as to how Kettleman should have been developed and produced, assuming by now that it is admitted that the subject of this paper is at least a pertinent question:

Had the field been developed strictly on a unit basis with the wells located scientifically around the fringe of the field in the "black oil" belt to take full advantage of the gas pressure down-structure from the "gas cap" and of the water moving up-structure from the edge, Appellants, owning property in the central portion of the field in Section 29-J would have initially been allocated few wells and little oil.

The prescription of development quoted above is probably as accurate as the requirements of Kettleman's present situation warrant.

For some further suggestion of the formulas or concepts under which Kettleman should have been operated the following is quoted from an article written by J. Arthur Sohn:

Two of the most interesting recent developments in Oklahoma exemplify the striking contrast between the wasteful methods of other days and the modern cooperative system. In the heart of the old Osage nation, in the peaceful, rolling pasture

land of northern Oklahoma, the South Burbank Pool is the scene of the most advanced unit operation ever attempted in the State.

No better example of the diversity in producing and operating methods utilized at the same time was ever manifest. In the early development of the Mansion field, as the new extension at Oklahoma City is called, gas was popped off into the air before facilities were available to handle it. At South Burbank, all of the available gas produced is returned to the sand by means of input wells to lift another load of oil in an endless cycle. Such is the difference in the use of nature's greatest gift to the operator—the natural energy generated by the pressure of the reservoir.

The purpose of the unitization was to gain the advantages of a single operator, thereby eliminating competitive drilling and duplication of equipment and supervision and to carry out a *pressure maintenance* program.

Only a dry hole can stop an oil field—it is probably still true. But a little cooperation can make it last longer, yield more and cost less. They far outweigh any temporary advantage. Gradually, from contrasting experiences like Oklahoma City and South Burbank, the industry is coming to realize that.*

At Kettleman competitive drilling is not eliminated. Oil is being left in the ground. Gas is being withdrawn not in the manner best adapted to recover maximum quantity of hydrocarbons but in the manner that will maintain a saturated outlet to the gas utilities. There is no pressure-maintenance program.

The foregoing gives the background of attempts at conservation and the tempo of development and producing operations that are responsible for the condition in which the North Dome of Kettleman Hills now finds itself. As accurately and briefly as the authors can state it, the following is the condition.

PRODUCING ZONES

The Temblor oil horizon at Kettleman Hills consists of hard sandstone, which is locally divided into many beds by thin layers of shale. The participating area of the field has been determined as 16,510 acres. For convenience of reference in the field and from an operating point of view the Temblor horizon has been divided into five zones as follows: First zone, 300 ft. thick; Second zone, 275 ft. Third zone, 175 ft. Fourth zone, 210 ft. Fifth zone, 345 to 425 ft. A sixth zone has made some production, which for the purpose of this discussion we may omit.

Subject to certain reservations, it can in general be said that the upper four zones inside the minus 5800-ft. subsea contour produce light 60° A.P.I. oil, together with a large gas-oil ratio varying from 20,000 to 100,000. This area is generally referred to as the "gas-cap area."

The area outside of the gas cap is known as the "black-oil zone." Black oil of 33° to 37° A.P.I. is produced from the Second, Third, Fourth

* J. A. Sohn: *Oil Weekly* (Sept. 21, 1936), reprinted from *The Lamp*.

and Fifth zones in the black-oil area. The gas-oil ratio in the black-oil area varies from 500 to 5000 but averages about 1500.

PRESSURE LOSSES

Volumetric withdrawals, assuming that 1000 cu. ft. of gas at the surface occupies the same space in the formation as a barrel of oil, from date of discovery to April 1, 1936, totaled 936,218,755 bbl., of which 125,168,499 bbl. represented oil and 811,050,256 bbl. represented gas. It is important to bear in mind that 86.6 per cent of the total volumetric withdrawals have been in the form of gas and only 13.4 per cent produced as oil with a gas-oil ratio higher than six to one.

Reservoir pressure is diminishing at an alarming rate. In the active producing areas losses during the two-year period ended in April 1936 vary from $\frac{1}{2}$ lb. per day in the Felix area to $1\frac{1}{2}$ lb. per day in the Huffman area.

On the basis of production at Kettleman Hills to April 1, 1936, there has been a decline of 1 lb. for each 41,000 bbl. of oil produced in the Huffman area and a decline of 1 lb. for each 23,500 bbl. of oil produced in the Felix area.

On March 28, 1935, the conclusions of the Petroleum Administrative Board with reference to the method of making intrafield allocations were embodied in an order of the Petroleum Administrator. The Board concluded that as a result of its consideration of evidence submitted subsurface pressure contours should be employed in the calculation of well allotments in a manner that would provide for the establishment of more uniform pressure gradients throughout the field. In its recommendations the Board attempted to establish a basis of volumetric withdrawals whereby volumes in the "gas-cap" area and in the "black oil" were balanced. Also incorporated in its recommendation was the requirement for determining the relative productivity of wells. By relative productivity was meant the comparative ability of a well to withdraw oil from the producing formations without causing excessive pressure gradients or other conditions conducive to waste.

Testimony presented before the Advisory Committee in Los Angeles by Kettleman Hills operators $2\frac{1}{2}$ years ago emphasized the importance of maintaining uniform pressures. Extended hearings before the Petroleum Administration Board in December 1934 further emphasized the necessity of conserving the gas energy.

DECLINE IN PRESSURE BY AREAS

The areas shown on the map of Kettleman Hills (Fig. 3) have come to be regarded as areas having certain distinct operating and producing characteristics. The Huffman and Felix areas have been competitive areas where the rate of development was established by operators whose lands

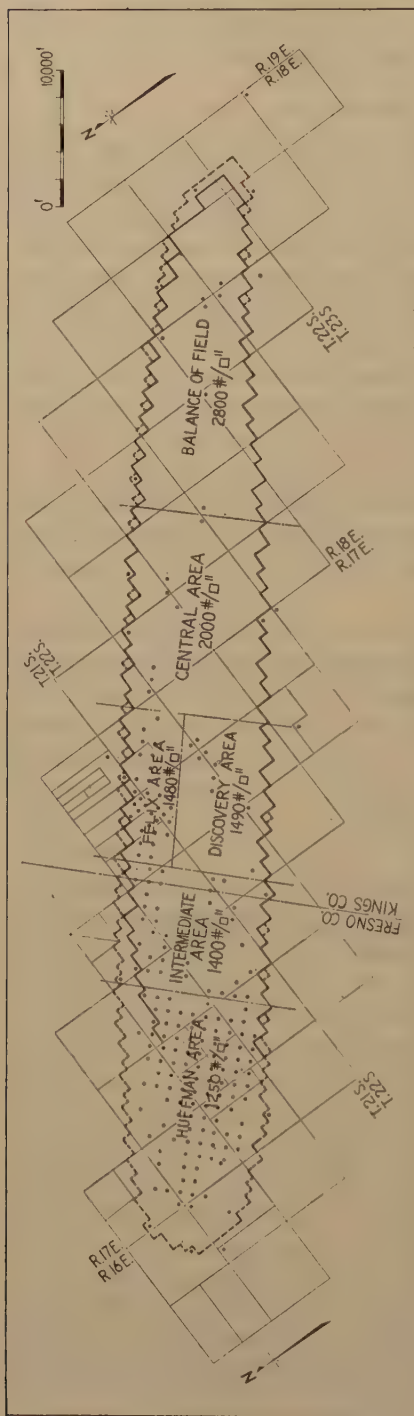


FIG. 3.—PRODUCING AREAS, NORTH DOME, KETTLEMAN HILLS.

were not included in the Unit Plan Agreement. The remaining four areas have been designated as the Intermediate, Discovery, Central and Balance of field on the south end. In Tables 2 and 3 are shown number of wells, area, pressures and volumetric withdrawals for each subdivision as of April 1, 1936.

The average bottom-hole pressure loss for the entire field has been 33.4 per cent. In arriving at this percentage loss, the south portion or area designated on Fig. 3 as "balance of the field" and representing 26 per cent of the entire area, is shown with original pressures still available. When it is found that 74 per cent of the entire field has suffered a loss in pressure of 33.4 per cent against a recovery of 125,000,000 bbl. of oil, there is occasion for serious concern. There is even more cause for alarm when facts are available to show that 55 per cent of the field has suffered a pressure loss of approximately 50 per cent with oil recovery of only 122 million barrels. If it is assumed that the 55 per cent of the field embraced within the Discovery, Felix, Intermediate and Huffman areas has already produced one-fourth of its ultimate production, accompanied by an actual pressure loss of 50 per cent, it is of more than academic interest to speculate on the cost of recovering the remaining reserves. Perhaps we are justified in borrowing an expression from the mining industry and refer to the past as "a high grading method."

PRESSURE MAINTENANCE ESSENTIAL TO PROFITABLE PRODUCTION

Pressure losses have been largely due to excessive gas withdrawals which result in the production of five to six volumes of gas per volume of oil. Some 20 high-ratio wells have contributed more to the depletion of reservoir energy than all the other wells in the field. Shutting in such

TABLE 2.—*Production Data*

Number of Wells	Area	Acres	Production		Average Static Bottom-hole Pressure ^a
			Barrels Oil	M. Cu. Ft. Gas	
84	Huffman	3,830	63,730,963	151,397,050	1,250
22	Intermediate	2,380	15,590,824	109,928,911	1,400
29	Felix	1,070	31,048,591	179,547,219	1,480
13	Discovery	1,690	10,959,110	353,794,898	1,490
7	Central	3,220	3,411,419	14,803,259	2,000
6	Balance	4,320	427,592	1,578,919	2,800
161		16,510	125,168,499	811,050,256	

^a Bottom hole pressures are all on the basis of a datum plane 7000 ft. below sea level and after 24-hr. shut-in.

TABLE 3.—*Pressure Loss by Areas*

Area	Acres	Assumed Original Pressure, Lb.	April 1, 1936 ^a Pressure, Lb.	Loss	
				Lb.	Per Cent
Huffman.....	3,830	2,800	1,250	1,550	55
Intermediate.....	2,380	2,800	1,400	1,400	50
Felix.....	1,070	2,800	1,480	1,320	47
Discovery.....	1,690	2,800	1,490	1,310	46.8
Central.....	3,220	2,800	2,000	800	28
Balance.....	4,320	2,800	2,800		
	16,510	2,800	1,863	937	33.4

^a All pressure data are on the basis of a datum plane 7000 ft. below sea level and after 24-hr. shut-in.

wells would do more good than shutting in all of the low-ratio wells. There is little doubt that the ultimate recovery from a field will be increased if the reservoir energy is utilized uniformly and evenly over the entire field. Low-pressure sinks allow premature water intrusion.

A recent survey of producing operations in the field shows 40 wells on gas-lift and 29 wells making a water cut of 10 per cent or more. This must be regarded as an impressive warning of the problems to be faced

in a field where, because of the depth of the wells, every precaution reasonably possible should have been exerted towards maintaining flowing conditions. There is justifiable cause for alarm when 69 wells out of a total of 183, on Sept. 1, show such effects.

Prospects of pumping oil from depths of 8000 to 9000 ft. are distinctly unfavorable, both physically and economically. Figures on the cost of pumping oil from the Clarke zone at Santa Fe Springs show a net fluid cost varying from 87¢ to \$1.77 per barrel. Various types of pumping equipment are being tried at the present time in the Kettleman Hills field, but thus far results have not been encouraging.

It is still possible to retard pressure losses, as production can be secured from wells with gas-oil ratios of 1000 ft. or less. If it is assumed that approximately 370 lb. is the minimum flowing pressure at which wells will continue to flow, we can expect an area covering approximately 2500 acres at the north end of the field to reach the critical point within the near future.

In the absence of a uniform water encroachment and a definite lag in the rate of encroachment, pressure maintenance becomes a matter of vital importance.

EFFECTS OF PRESSURE REDUCTION

Evidence has become available to show that edge water is not encroaching fast enough to maintain pressure. This reduction in pressure is not confined solely to the competitive areas but is spreading to wells 3 to 6 miles from production.

Loss of reservoir pressure affects ultimate recovery of oil in two ways—by removing the energy necessary to move the oil to the bottom of the well and by increasing the resistance of the flow through increase in viscosity and surface tension.

Gas production at Kettleman Hills can be materially reduced. We have heard much of the correlative rights of property owners in a common pool and there is to be found no more direct application of this doctrine than in the correlative rights to the reservoir energy. Thus it should be possible to promote the most efficient and economical recovery of the maximum volume of oil and to prevent the waste of this energy through premature gas withdrawals made for the sole purpose of converting that gas into immediate cash realization. At Kettleman Hills, gas production and gas-oil ratios are optional with operators, the great majority of whom are seriously concerned with the alarming loss of pressure.

It is believed that ample engineering data are available to show that present production methods are wasteful and injurious to the field; that pressure is diminishing at an alarming rate; that water encroachment is not fast enough to maintain pressure and that if present practices are continued the ultimate recovery from the field will be less than half of

what it would be if unnecessary gas production were deferred until after the oil had been produced.

CONCLUSIONS

The authors desire to emphasize the following facts and considerations:

1. Subsurface pressure is dropping at an alarming rate.
2. Pressure maintenance is essential to facilitate the flow of oil to wells.
3. Loss of pressure not only affects the motive force but results in increased viscosity and resistance to flow.
4. Pressure loss is largely due to excessive gas production.
5. Low ratios are attainable.
6. Pressure maintenance will result in higher recovery of oil.

Some operators at Kettleman submitted to unitization unwillingly or at least with considerable misgiving. It certainly has been no disadvantage to the so-called outsiders. Unless a field is subject 100 per cent to a unified policy of development and production there is no unit operation. At best it is: "cooperative operation" with loose ends varying in importance from slight annoyance to complete domination.

Unfortunately, these conditions have resulted from factors beyond the control of the Association and its Board of Directors. These evils have been continued in spite of repeated protests on the part of directors and members who have endeavored to support the original purposes of the Unit Plan.

Practically, the authors believe that unit operation is not the complete answer to proper oil-field development and production. So much has been said about the "rule of capture" that no attempt will be made here to discuss it in detail. Let it suffice to say that the "rule of capture" is not a law. It is, as expressed by a legal friend, a shield rather than a sword. Unfortunately, it is used as the shield of greed; the antithesis of cooperative effort. When it is finally recognized that the energy of a pool as well as its valuable contents are the common property of all and that no single individual may so use his property as to injure his neighbor, then, perhaps, relief may be found in the courts for such a situation as we have herein shown to exist.

DISCUSSION

(R. P. McLaughlin presiding)

A. H. BELL,* Los Angeles, Calif.—I think Mr. Watson has been ultraconservative in assuming 2800 lb. as the original pressure. The pressure on the casing of the Marland well before it blew out was 2350 lb., and undoubtedly the reservoir pressure was greater than 450 lb. more than the surface pressure. And, because of the high

* General Superintendent, Continental Oil Co.

pressures recorded at the surface of North Belridge, and in the face of the similarity of the two structures, I think that estimates of 3200 lb. are more correct for Kettleman Hills. If that is true, Mr. Watson's figures would be magnified just that much more. The situation would be more serious than he has claimed.

J. JENSEN,* Los Angeles, Calif.—I can agree with most parts of this paper. The Associated Oil Co. recognized the importance and value of saving gas. In the field where it and the Shell Company were able to do so, it began in 1930 to follow out just that kind of a practice. Its production of oil has been at a gas-oil ratio at times as low as 2600 cu. ft. of gas per barrel of oil. At no time was the gas production very great. Our ratios now are down even lower than this. There is no doubt about the value of conserving gas and making use of it. The illustration of the effect of loss of pressure I like to harp on, as Mr. McLaughlin says, is the Associated well, which came in with 13,950 bbl. of oil per day. I do not think we got more than 50,000 bbl. of oil out of that well because of the taking away of the gas. That well lost its power to produce because of the diminishing of gas pressure.

What Mr. Watson says is very true about the law of capture in the production of oil at Kettleman Hills. Some of the operators, themselves, were entirely unable to control their lessors. I know the Associated people made a very strong appeal, but with no result. Associated Oil Company believes very much in producing oil at a low ratio, and during the proceedings at Kettleman Hills made the proposal that oil should be produced throughout the state at a low ratio.

G. V. D. MARX,† San Francisco, Calif.—I heartily agree with many of the statements, but there are one or two questions I should like to ask Mr. Watson. Toward the end of the paper the authors state that the pressure loss is largely due to excessive gas production, while in the earlier part of the paper they refer to the expansion of the gas cap. I am curious as to how these two statements can be reconciled. If the gas cap is expanding it seems to me it must be expanding into areas of lower pressure than exist in the gas cap.

There was a figure given—I think 50 per cent—of the estimated production that would be lost because of the practices followed. Is it possible that there is sufficient gas reserve at Kettleman to form an extra cushion over the amount necessary to drive oil to wells and produce it from them? Incidentally, what is Mr. Watson's idea of the original formation gas-oil ratio as compared to the producing ratio to date? I believe his figure for the latter was eight to one. Is this greater or less than the original formation gas-oil ratio?

And one slight correction I should like to make: Mr. Watson said that until the last few days before the Association was consummated those men intimately connected with the work understood that the participation was going to be 100 per cent. I believe that that is not quite true—at least so far as the Standard Oil Co. is concerned. Some six or seven months before the organization was formed those most intimately connected with the Association knew that the Standard Oil Co. would not become a member of the Association but would cooperate with the Association.

C. P. WATSON.—I am merely calling attention to the conditions that are based on accumulative engineering data. The pressures have gone down in the field. We assume that we have taken out one-fifth of the oil. We have been wasteful of the energy. I do not know the amount of formation gas that is with the oil. We should be glad to have any information on that. There is very definite evidence that the methods of producing the oil and gas are wasteful. The expansion of the gas cap is

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especially noticeable. If you take the volume withdrawals you get some idea of the space that the gas is occupying in the reservoir, and you will see that the gas taken out has occupied a much greater space than the total volume of oil. I think the conditions now certainly point to the necessity of careful production at low gas-oil ratios.

As to the statement "Until the last few days of . . . negotiation it was assumed . . . that the Unit Agreement would be 100 per cent effective," I wish to point out that reference is made specifically to the *Unit Agreement* and it was known all along, by all parties, that the Standard Oil Co., as to its 9500 acres of fee lands, was not intended to be a party to that particular agreement. The reference is to those companies that did not sign the agreement although their names appear in Article XIII of the final printed draft of the *Unit Agreement*.

G. V. D. MARX.—From a previous study that I made of the trend of pressure decline, particularly in the north end of the field, there has been recently a very noticeable flattening of the rate of pressure decline. In other words, the low-pressure area has so spread that the entire area is going down much more gradually, and I do not think the situation is quite as bad as indicated by Mr. Watson.

J. M. LOVEJOY,* New York, N. Y.—Would Mr. Marx develop a little further his theories in connection with the expansion of the gas cap? As I understood his comment, it was to the effect that as long as there is a low-pressure point with a lower pressure than that existing in the gas cap there is no danger if we take gas from the gas cap. If that is not correct, I would like to have him correct me. There is something in that; it is perhaps that we would tend to offset the drainage into the low-pressure area by taking gas from the gas cap and lowering pressure there. What would pressures be in the whole field when the pressure in the gas cap was brought down to the pressure in the competitive area?

G. V. D. MARX.—I really was not propounding a theory of my own, I was asking for information from Mr. Watson, but what I had in the back of my mind was this: In watching the history of the production at Kettleman there is no doubt that the withdrawal of oil and gas from certain down-structure points is taking place more rapidly than the edge water is able to come in and maintain the pressure, resulting in some advance in low-pressure areas. Although there was a tremendous amount of gas taken out of the so-called gas cap, the amount was insufficient to offset the down-structure withdrawals, and there has been a progressive movement down-structure of the interface, which once may have been around minus 6000 ft., or thereabouts (but probably never a single interface); but in any event the whole gas face has moved down structure despite the fact that there has been a large amount of gas taken out up structure.

What the effect of continued withdrawals might be, I do not know; but I was wondering and speculating, if the rate of gas withdrawal was no greater than the formation gas-oil ratio that existed originally, is current production or production in the future being robbed of any energy it should have to produce the oil? I do not know the answer to this question. I have sometimes thought, and have heard it argued, that the ideal way to produce a field that has a gas cap is not to maintain the gas cap intact but to attempt to maintain the gas-oil interface at its original position. I am inclined to believe that there is at least a question that might be argued on both sides without respect to any particular field, because whenever we get involved in an argument on any particular field other things enter in and cloud the issue.

* President, Seaboard Oil Co. of Delaware.

S. C. HEROLD,* Glendale Calif.—I feel that the authors are somewhat pessimistic. I believe I am more optimistic than they are with respect to the situation at Kettleman Hills. The abnormal decline in pressure that has been marked in the competitive areas does not alarm me excessively. Mr. Marx has now informed us that the curve of pressure decline is flattening out. May I add that it is going to flatten out more in the future. I do not know when. There will be a time when the curve of decline must become almost flat. That is to say, continued production will take place without further decline in pressure until the day when water arrives at the wells, and then we shall have just so many barrels of water instead of oil. Of course, this replacement of water for oil will take place gradually at the wells located up structure.

Where there are reservoirs of oil and gas, with great quantities of gas, there must necessarily be bubbles of gas throughout the mass of oil in the formations of the reservoir. This gas in the initial states of production must expand and gives what we call gusher production. During this period the gas actually does work in forcing the oil to the bottom of the well. But the day must arrive, as a matter of fact it did arrive for the original Milham well about nine months after the initial production, when the work by gas expansion ceased, the water on the edge of the pool started to move and the gas thereafter only expanded to accommodate itself to a decreased pressure in the vicinity of the well. It did no further work in forcing the oil to the bottom of the hole.

Gas increases in its space occupancy, as we know, when pressure declines. That means simply that more pores in the formation are filled with gas after the expansion than there were before. In any event these pores filled with gas still maintain globules of oil between them in the channels that connect the pores, and these globules resist the pressure of the reservoir. They check the movement of the oil and water toward the well; the water on the edge is unable to keep up the pressure at the bottom of the hole, and consequently there is an abnormal decline of pressure immediately surrounding the well.

The increase in bubbles has been taking place in the Kettleman reservoir ever since its discovery. It seems to me that we are about due for a change in the situation, so that the number of bubbles will become constant in the vicinity of the wells now existing, and as soon as this happens the pressure must continue about on an even basis for further production.

There are many things that I should like to mention with respect to the Kettleman reservoir and others that are somewhat similar, time is short now. Ideas resulting from recent studies may be right or wrong. It would be well for us to attempt a selection of events and conditions within a reservoir that may be correct and worthy of our consideration in the future development of the field and in the further manipulation of the wells.

* Consulting Engineer.

Chapter IV. Petroleum Economics

Status and Outlook of Petroleum—Supply, Demand and Stocks

BY FRED VAN COVERN*

(New York Meeting, February, 1937)

BEFORE getting into a discussion of the subject of my paper, I want first to make it clear to everyone that I am speaking as an individual; and that any expressions of opinion that are contained herein, or may be expressed in any oral discussion that may follow its presentation, are entirely my own, and must not be construed to be the official opinion of the American Petroleum Institute.

DEMAND FOR MOTOR FUEL, 1936

During the year just closed the domestic demand for gasoline exceeded 481 million barrels. This compares with 434,810,000 bbl. consumed during 1935 and indicates an increase of 10.46 per cent. Export shipments amounted to 27,831,000 bbl. while in 1935 they totaled 30,613,000 bbl. Total demand, therefore, was 509,422,000 bbl., or 9.16 per cent above the 465,423,000 bbl. of 1935.

Following are the figures for several years:

Year	Domestic	Export	Total
1932	377,791,000	35,438,000	413,229,000
1933	380,494,000	29,321,000	409,815,000
1934	410,339,000	24,686,000	435,025,000
1935	434,810,000	30,613,000	465,423,000
1936	481,591,000	27,831,000	509,422,000

Already we are supplying gasoline domestically and as foreign shipments at a rate almost 25 per cent greater than our low level of 1933.

Before giving figures for 1937, I should like to spend a moment or two in discussion of gasoline inventories, from the point of view of minimum working stocks and other requirements and of probable actual levels.

INVENTORIES OF GASOLINE

The year 1936 closed with about 62,900,000 bbl. of finished and unfinished gasoline in storage—about 6 million barrels more than was on hand

Manuscript received at the office of the Institute Feb. 15, 1937. Condensed March, 1937.

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at the end of 1935. On March 31, 1936, we had in storage 74,485,000 bbl. What will be on hand on March 31, 1937, and how much do we actually need in storage as of that date? In this connection a tabulation that recently was made contains much of interest (Table 1).

We all recall the work done by the Planning and Coordination Committee during the code period, in an effort to ascertain how much gasoline the industry actually needed in order conveniently and economically to carry on its business. Starting with that as a base and attempting to bring the figures up to date, we find the estimated required working stocks of motor fuel (finished and unfinished gasoline) as of the dates indicated in Table 1.

TABLE 1.—*Estimate of Required Working Stocks of Motor Fuel*
Barrels of 42 gallons.

	September 30		
	1935	1936	1937
Capacity of gasoline-motor fuel tankage wherever located.....	106,546,000	108,000,000	110,000,000
Tank bottoms.....	7,253,000	7,400,000	7,500,000
Refineries:			
Unavailable unblended finished.....	8,416,000	9,400,000	10,100,000
Unavailable unfinished.....	4,361,000	4,700,000	5,000,000
In lines and operating equipment.....	671,000	700,000	700,000
Special light tops (refrigerated storage, etc.)	600,000	600,000	600,000
Filter-house naphtha not in solution.....	400,000	450,000	500,000
Pipe lines:			
Line-fill, operating reserves and as tenders..	2,049,000	2,100,000	2,100,000
Amount in transit throughout systems.....	604,000	600,000	600,000
In marine transit from California and Gulf Coast:			
Allowance for tanker fill.....	2,553,000	2,900,000	3,300,000
Terminals:			
Protection of points supplied by tankers...	4,428,000	4,500,000	4,600,000
Frozen (icebound) and other irreducible seasonal.....	5,265,000	5,750,000	6,200,000
Undistributed.....	400,000	400,000	400,000
Total Fixed Unavailable.....	37,000,000	39,500,000	41,600,000
Shipping stocks.....	13,000,000	14,200,000	15,400,000
Total Working Stocks Required.....	50,000,000	53,700,000	57,000,000

From the foregoing it will be seen that the total fixed unavailable gasoline required to operate refineries, terminals and transportation facilities, while at the same time assuring sufficient supplies, and before navigable waters become frozen over, at terminal and bulk points which

cannot be reached by water transport during the winter, is something over 41 million barrels. In other words, we need that much gasoline to keep our refineries, transportation and supply systems operating. That does not, however, provide any gasoline for shipment to consumers. It represents only bare working levels.

TABLE 2.—*Suggested Method for Calculating Required Inventories on Any Given Date with Certain Tie-posts Known^a*

	If the Demand upon Refiners for Finished and Unfinished Gasoline Should Be as Follows ^b	Index of Operation	Refinery Gasoline Production, Bbl.		Change in Stocks	Monthly Inventory Levels
			Daily	Monthly		
1936						
Sept. 30.....						53,700,000
October.....	46,000,000	100.0	1,456,000	45,140,000	— 860,000	52,840,000
November.....	41,800,000	95.0	1,383,000	41,490,000	— 310,000	52,530,000
December.....	39,500,000	95.0	1,383,000	42,870,000	+ 3,370,000	55,900,000
1937						
January.....	36,200,000	95.0	1,383,000	42,870,000	+ 6,670,000	62,570,000
February.....	32,900,000	97.5	1,420,000	39,760,000	+ 6,860,000	69,430,000
March.....	40,000,000	97.5	1,420,000	44,020,000	+ 4,020,000	73,450,000
	236,400,000			256,150,000	+19,750,000	
April.....	42,900,000	100.0	1,456,000	43,680,000	+ 780,000	74,230,000
May.....	47,300,000	100.0	1,456,000	45,140,000	— 2,160,000	72,070,000
June.....	48,700,000	105.0	1,529,000	45,860,000	— 2,840,000	69,230,000
July.....	51,500,000	105.0	1,529,000	47,300,000	— 4,200,000	65,030,000
August.....	51,900,000	105.0	1,529,000	47,300,000	— 4,600,000	60,430,000
September.....	49,300,000	105.0	1,529,000	45,870,000	— 3,430,000	57,000,000
				275,150,000	—16,450,000	
	528,000,000					
Plus 3,300,000 added to stocks	3,300,000					
	531,300,000			531,300,000		

^a Calculation based upon following assumptions: (1) that 53,700,000 bbl. of finished and unfinished gasoline would have been sufficient inventory as of Sept. 30, 1936; (2) that 57,000,000 bbl. will be sufficient as of Sept. 30, 1937; (3) that the demand upon refiners for finished and unfinished gasoline during the year ended Sept. 30, 1937 will be approximately 528,000,000 bbl.; (4) that if the above indicated figure of inventories had been realized on Sept. 30, 1936, and if the Sept. 30, 1937, figure is to be realized, it would have been necessary for refiners to have contemplated a production of 531,300,000 bbl. during the 12 months period. (On an even-keel operating basis, this would have called for the production of 1,456,000 bbl. of this gasoline daily during the year, but the industry does not, as a unit, operate on an even-keel basis.) Assumption (5) that a 10 to 15 per cent fluctuation in the rate of manufacture is not excessive.

^b Must not be compared with total demand for motor fuel.

September 30 generally represents, for the country as a whole, the date upon which seasonal stocks are at their minimum, but refiners must have, even as of that date, sufficient gasoline above fixed unavailable to insure prompt fulfillment of the then current orders. A credit should be allowed on this basis. For Sept. 30, 1937, that figure has been placed in the table at 15,400,000 bbl. This gives a total working stock requirement on the date mentioned of 57 million barrels and infers the added responsibility

that at no time during 1937 high-consuming season, ending perhaps on Sept. 30, can stocks of finished and unfinished gasoline go below that figure if the industry is to operate economically and conveniently.

The next question is: How much does the industry need at the beginning of the next high-consuming season, say, on March 31, 1937? Table 2 presents a method of approximate calculation of that figure as well as a seasonal range of the inventory requirements of the entire industry.

PROBABLE INVENTORIES, MARCH 31, 1937

As was indicated earlier, 1936 ended with a finished and unfinished gasoline inventory of 62,900,000 bbl. On Jan. 31, 1937, it was estimated that 69,200,000 bbl. was in storage; and on Feb. 6 a possible 70,500,000. If the industry continues to run crude oil to stills during the period from the latter date to March 31, at the rate established during the four weeks ended Feb. 6, about 3 million barrels per day, we may see a 78 to 80 million-barrel level.

The question arises then as to whether 78 to 80 million barrels actually in storage at the end of the winter, in relation to a possible indicated requirement of about 73½ million, taken in conjunction with an expected increase in demand for motor fuel of over 8 per cent, and perhaps 290 million barrels of crude oil in storage above ground, is any greater threat to stability than the 74½ million barrels of gasoline in storage on March 31, 1936 in relation to a possible minimum requirement at that time of 70 million and 315 million barrels of crude inventory; proration of crude-oil production assumed as being equal.

TABLE 3.—*Days Supply of Motor Fuel March 31, 1936, Actual vs. March 31, 1937, Probable*
Barrels of 42 Gallons

	1936	1937
Probable total requirements (including fixed unavailable shipping stocks and seasonal requirements).....	70,000,000	73,500,000
Actual or estimated actual.....	74,485,000	80,000,000
Minimum working requirements (fixed unavailable, shipping stocks and irreducible seasonals).....	53,700,000	57,000,000
Actual or estimated available for shipment.....	20,785,000	23,000,000
Actual or anticipated actual daily shipment following summer season (April–September).....	1,480,000	1,590,000
Days supply on hand available for shipping.....	14.0	14.5

It would, of course, be difficult to defend the position that 78 to 80 million barrels would not contain a surplus. However, it would appear that relatively it would contain very little more or less than last year's 74½ million barrels. But it is a fact, I believe, that last year's summer season

did show the effects of whatever surplus may have existed. The industry, therefore, should closely watch its runs to stills in relation to the actual demand for distillate fuel and required gasoline inventories, during the remainder of the winter, so that the burden it will carry into the summer season in the form of surplus gasoline may be kept as low as possible.

DEMAND FOR MOTOR FUEL, 1937

For the year 1937 I had intended laying on the table an estimate of domestic demand of 520 million barrels and an export shipment of not less than 29 million; or a total demand of 549 million barrels. These figures would show an increase in domestic demand of 8.27 per cent and in total demand of 8.06 per cent, both on a daily average basis. Since arriving at these totals, I have at times become somewhat alarmed at the potentialities involved in certain recent industrial disturbances, and other occurrences, but at the moment prefer to leave the year's total unchanged.

Also since having made them up, we have had an opportunity through preliminary estimates to have observed the actual demand for the month of January 1937. It appears from these early figures that, owing to the very fine weather during that month, demand was perhaps 2 million barrels or more greater than could normally have been expected.

While cutting down the demand for heating oils, weather conditions have abnormally increased gasoline consumption, in that way holding gasoline inventories down correspondingly. I believe the two trends of demand will coincide a little later in the year but perhaps not before it has caused a revision in the year's domestic total to 522 million barrels.

While the calculation in Table 2 is based upon a maximum fluctuation in refinery output of 10 per cent, recent trends of seasonal operation have shown a tendency to level off. This is probably being brought about because of the current relationship between fuel oil and gasoline demand and may be the beginning of a definite change from previously established seasonal trends of runs to stills. It would appear, however, that more even-keel operation of refineries, while desirable from the angle of its effect upon crude-oil production requirements, would tend to build up gasoline inventories during the winter to higher levels, necessitating considerably larger than usual withdrawals during the months in which consumption is high.

CRUDE-OIL INVENTORIES

On May 31, 1922, there were 289,069,000 bbl. of crude oil in storage. During the following years these stocks rose and fell but mainly continued upward until on Oct. 31, 1929, we found 433,500,000 bbl. accumulated. This was our industry's all-time peak. On Dec. 31, 1936, these stocks were down to about 288,200,000 and on Jan. 23 were at 285,500,000 bbl., or right back again at the level that existed early in 1922.

Table 4 lists these stocks by fields of origin on Dec. 31, 1929, Dec. 31, 1935, and Dec. 31, 1936.

TABLE 4.—*Stocks of Crude Oil by Fields of Origin*

	Dec. 31, 1929	Dec. 31, 1935	Dec. 31, 1936
Pennsylvania grade.....	7,168,000	4,599,000	4,324,000
Other Appalachian (incl. Kentucky).....	1,793,000	897,000	1,015,000
Lima-Northeast Indiana-Michigan.....	806,000	1,295,000	1,032,000
Illinois-Southwest Indiana.....	10,631,000	10,968,000	9,676,000
North Louisiana and Arkansas.....	26,753,000	9,676,000	10,922,000
West Texas and Southeast New Mexico.....	58,172,000	29,509,000	28,606,000
East Texas.....	^a	21,589,000	20,674,000
Oklahoma-Kansas-North Texas, etc.....	216,044,000	132,884,000	116,653,000
Gulf Coast.....	27,684,000	26,368,000	25,243,000
Rocky Mountain.....	26,017,000	27,251,000	26,147,000
California.....	41,094,000 ^b	35,545,000	30,936,000
Foreign.....	6,085,000	3,745,000	2,117,000
Lease (producers) stocks.....	6,198,000	10,529,000	10,839,000
Total United States.....	428,445,000	314,855,000	288,184,000

^a Included with Oklahoma, Kansas, North Texas, etc. prior to August 1933.

^b Includes lease (producers) stocks prior to January 1933.

These inventories must be pretty closely approaching working levels. No information is yet available as a result of the effort being made by the U. S. Bureau of Mines to determine required inventories. It is my opinion, however, that 250 million barrels represents about the minimum level to which this inventory should go, but I am inclined to believe that this might possibly result in uneconomic operation. No doubt, there already are some companies that are short of crude stocks. Any actually existing surplus must be in the hands of relatively few units.

I think that 275 million barrels properly and equitably distributed by grades, location and companies would more nearly represent economically desirable levels and permit convenient and proper operation. Just what this requirement is, however, will not become known until the Bureau has finished its survey.

FUEL OIL

Contemplation of the demand for crude oil and refined products during 1937 has developed many interesting angles. One is inclined to wonder whether the industry has not already progressed well into another stage of its development. Not so very long ago, refiners were mainly interested in the production and sale of kerosene, with gasoline a very undesirable by-product. The internal-combustion gasoline engine changed all that and with its growth a necessarily large production of fuel oil found a market, but in competition with coal. Advances in the art of refining,

the advent of the home-heating oil burner and the rapidly increasing demand for distillate fuels are again greatly changing the picture. This is seemingly forcing the light fuel oil portion of the barrel of crude into the principal-product class, making gasoline share this distinction with it, in perhaps a new phase in the industry's advance. Heavy fuel oil is perhaps being pushed farther and farther into the background than ever.

In further explanation of the point I have in mind, let me say that I look upon the supplying of the demand for motor fuel as the direct responsibility of the American petroleum industry, and that it should meet the demand for that product in all its potentialities. I believe further that it has a responsibility in connection with the complete potential market for distillate fuel oils. For both of these fuels, and for lubricants and kerosene and the lesser products, I look at their respective potential markets as a demand upon the industry for products of its raw material. In regard to residual fuel oil, I am inclined to use the word "sales" instead of "demand." In other words, I believe that the interests of the American producer and refiner of high-grade American gasoline-bearing crude are best served by treating the production of residual fuel oil strictly as a by-product incident to the balancing of supply and demand of gasoline and distillate fuel oil—and that only as much domestic residual fuel oil should be available for sale, in relation to the total potential market for that product, as is incidentally produced in supplying the demand for gasoline, distillate fuel oils, lubricants, kerosene and the less important products. I believe it reasonable, then, to think that in a balanced picture observed from the point of view of the American producer and refiner of crude oil and of the public, if the growing essential market for residual fuel oil is to be supplied, and cannot be supplied in balance with gasoline and distillates, imports of fuel oil must be increased or the domestic industry must find itself in an almost constant state of instability in attempting to supply that oil—further, that American refiners should concentrate on the manufacture of the now principal products and base their runs to stills upon the demand therefor in relation to desirable inventories thereof, if the American industry is to remain in a stable condition.

Perhaps it need not be brought out here, but the distinction, attained by distillate fuel forcing gasoline to share with it the principal-product class, brings added responsibility—the responsibility in the case in point being the necessity of sharing a greater part of the cost of the raw material and contributing a greater proportion than now of the total income of the industry.

You recall what occurred in the gasoline-distillate fuel-oil situation during the 1935-1936 winter season, when the large demand for home-heating fuels, definitely out of relationship with the demand for gasoline motor fuel, and the basic yields of these two products, caused the piling up in storage of unnecessarily large amounts of gasoline. It was feared,

earlier in this winter, that this might happen again this year, but while refiners seemingly kept up runs to stills in anticipation of continued high gasoline consumption and a big season in home-heating oils, the weather in areas in which this type of heating is more generally concentrated has been extremely mild in comparison. The figures in Table 5 indicate the sales and number of burners operating.

TABLE 5.—*Number of Domestic Oil Burners*

	Sales during Year	Operating at End of Year
1930.....	126,400	665,100
1931.....	104,000	760,800
1932.....	86,200	843,200
1933.....	89,300	920,300
1934.....	110,100	1,014,100
1935.....	156,700	1,154,700
1936 (estimated).....	220,000	1,352,000

The demand for home-heating oils, other distillate fuel and gas oil is shown in Table 6.

TABLE 6.—*Demand for Heating Oil and Distillate Fuel*
Figures in Barrels of 42 Gallons

	Home-heating Oil Demand ^a		Other Gas Oil and Distillate Fuel Demand		Total Gas Oil and Distillate Fuel Demand	
	Barrels	Per Cent Change	Barrels	Per Cent Change	Barrels	Per Cent Change
1932	32,814,000		33,287,000		65,101,000	
1933	35,190,000	+ 7.24	29,558,000	-11.20	64,748,000	- 0.96
1934	40,472,000	+15.01	34,352,000	+16.22	74,824,000	+15.56
1935	49,903,000	+23.30	36,647,000	+ 6.68	86,550,000	+15.67
1936	60,178,000	+20.59	43,387,000	+18.39	103,565,000	+19.66

^a Portion of figure for total demand for heating oil published by the U. S. Bureau of Mines, estimated on the basis of average number of domestic burners in use. Bureau of Mines' heating-oil figures for 1936 not yet available.

By selected districts east of California we find the inventories of distillate fuels given in Table 7.

The combined effect of the relatively warmer weather in the more important domestic oil-burner regions this year compared with last, and the continued high rate of crude oil run to stills, is making itself felt in these inventories as well as in motor fuel. The problem seems to be how to produce more distillate fuel and less gasoline of required octane rating. One way might be to expand our gasoline re-forming facilities, but this at a considerable expense. Another way might entail a further advance

in the viscosity-breaking of the present production of residual fuel oil in order to supply larger quantities of distillate fuel. While not definitely noticeable in the statistics of the industry, these trends no doubt are now developing and will develop further as the mechanical problems and the economics of the supply and demand of gasoline and distillate fuel work toward a solution.

TABLE 7.—*Inventories of Distillate Fuels*
Barrels of 42 Gallons

Date	East Coast	Texas Gulf	Louisiana Gulf	Indiana-Illinois-Kentucky
Dec. 31, 1935.....	4,181,000	3,638,000	1,617,000	1,716,000
Jan. 31, 1936.....	2,888,000	3,113,000	1,378,000	1,148,000
Feb. 29.....	2,214,000	2,453,000	762,000	907,000
March 31.....	2,679,000	2,366,000	829,000	1,075,000
Dec. 31, 1936.....	4,433,000	3,376,000	1,024,000	2,508,000
Jan. 31, 1937 ^a	4,099,000	3,128,000	864,000	2,168,000
Feb. 6, 1937 ^a	4,047,000	3,091,000	837,000	2,118,000

^a Estimated.

Contrary to the trend in distillate fuels, we find here what might be called a tightening situation. Again we find high-grade American gasoline-bearing crude, a balanced domestic industry and imports all bound together in a very interesting, though involved, relationship.

TABLE 8.—*Residual Fuel-oil Inventories*
Barrels of 42 Gallons

	East Coast	Texas Gulf	Louisiana Gulf	Oklahoma-Kansas
Dec. 31, 1935.....	4,282,000	7,537,000	2,592,000	3,270,000
Jan. 31, 1936.....	3,857,000	6,256,000	2,265,000	3,198,000
Feb. 29.....	3,921,000	5,345,000	1,712,000	2,785,000
Mar. 31.....	4,274,000	4,857,000	1,303,000	2,702,000
Dec. 31, 1936.....	5,046,000	4,380,000	998,000	2,452,000
Jan. 31, 1937 ^a	4,281,000	4,834,000	1,074,000	2,361,000
Feb. 6, 1937 ^a	4,024,000	4,683,000	1,020,000	2,334,000

^a Estimated.

1937 CRUDE REQUIREMENTS

As was indicated earlier, my figures now show an expected total demand for motor fuel during 1937 of 549 million barrels. I think 11,000,000 may be supplied from benzol and natural gasoline moving direct.

Natural gasoline may be blended at refineries on an average of about 6.7 per cent and the average yield of gasoline from crude oil on the basis explained in my paper of a year ago (*Oil Weekly*, Feb. 24, 1936) may be 44.2 per cent.

ESTIMATES FOR 1937

	BARRELS
Runs to stills.....	1,123,000,000
Exports.....	52,000,000
Used as such and transferred to fuel oil in California....	44,000,000
Imports.....	30,000,000
Total demand for domestic:	
Crude oil.....	1,189,000,000
Daily average.....	3,260,000

How much of the above can be withdrawn from storage is, as we said earlier, a question difficult to answer. Those in the industry concerned with such problems need no more important piece of information than the results of the Bureau of Mines' study of crude-oil requirements.

Much was written during 1936 in calling attention to the creation of new highs in crude-oil production. Not many writers, however, went to the trouble to determine whether or not crude oil or product inventories were being adversely affected thereby. True, we did have some surplus gasoline inventory but the point is raised here that 1937 will again see some new crude-oil producing highs as the consuming season develops, but that fact, of itself, will not necessarily mean that the oil is not needed or that the situation is getting out of control.

Chronological Aspects of American Oil-reserve Replenishment, with a Note on the Contemporary Situation

By H. J. WASSON,* MEMBER A.I.M.E.

(New York Meeting, February, 1937)

PUBLISHED literature regarding the nation's oil reserve has been largely concerned with the estimated quantities in sight in known producing fields. This proved reserve has never been large in relation to demand. It has been the practice to consider the total future reserve (beyond that in sight within known fields) in the light of the broad potentialities of vast areas of partially explored sedimentary rocks, which are regarded as possible oil territory. Until recently, but little attention has been given to the rate at which the unexplored potentialities may be converted into the proved reserve classification.

To a certain extent, therefore, our contemporary viewpoint on the subject of national oil reserves is characterized by a pronounced contradiction. On the one hand, we measure known reserves as sufficient for only a few years of consumption—i.e., relative scarcity; on the other hand, we are confident that millions of unexplored acres will yield many new oil fields and that countless deeper productive formations underlie many of our known productive fields—i.e., infinite abundance.

Of greater significance than the quantitative measure of either of these reserve classifications is the rate at which reserve replenishment must be accomplished in order to maintain an adequate time supply of proved oil reserves.

The accumulation of geological data covering broad areas supports the belief that the remaining undiscovered oil reserve is exceedingly large. The distribution of oil in sedimentary formations of practically all ages, from Cambrian to Recent, is suggestive of almost unlimited possibilities; and the relatively small proportion of these possible areas that has been intensively explored in this country is a further index of the probable magnitude of the undiscovered future reserve.

The implication that may reasonably be drawn from these observations is that oil, though distributed with less regularity and concentration than its related hydrocarbon, coal, nevertheless is a relatively abundant natural commodity of which the exhaustion appears remote. Final exhaustion of our oil reserve, if not infinitely remote, is a future contin-

Manuscript received at the office of the Institute Feb. 12, 1937.

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gency so far removed as to be of small practical concern at this time, at least in the author's opinion. Accordingly, the first premise of this discussion is that oil itself is relatively not scarce—that the American oil reserve, most of which is probably undiscovered, is a quantity sufficient to supply the nation's needs for a period of several decades.

The commonly used term "scarcity" has a significant meaning, but it is more closely related to frequency of discovery than to volume of oil reserve itself. Thus we might denote a period of infrequent or subnormal oil discoveries as being one of temporary scarcity. But such usage should not necessarily imply a threatened contraction of the ultimate reserve of the country.

In respect to the known proved reserves, a much more precise unit of economic measurement than degree of scarcity is at hand; that is, "time supply in terms of years' demand." Obviously, it is of prime importance from a great number of considerations that proved oil resources be adequate for the nation's needs; and it is equally important, from the oil industry's viewpoint at least, to recognize and measure any excesses of potential reserve that might adversely affect market values of its products.

Frequent references have been made to estimates of the nation's oil reserve in terms of years' supply. The practical value of such estimates has suffered from the fact that they have been related to widely spaced reference dates whereas the problem of oil-reserve measurement logically lends itself to much closer chronological analysis. Furthermore, some confusion has existed in the underlying definitions of the reserve factors entering into the various calculations.

The general concept used in classifying mineral ore reserves—"proved, probable and possible"—is not applicable to oil, the history of which has been associated with a much higher new discovery rate than has been true of the minerals. Thus the "possible" oil reserve, even though not localized, is a thing that observation and experience teaches us will develop into proved reserves at rates more or less in relation to necessity and the consequent intensity of search. This generality must inevitably lose significance as the prospective but unexplored area becomes appreciably restricted. However, the accumulated evidence of exploration indicates that oil scarcity in this final sense is still a remote relationship of only theoretical importance at present. For all practical purposes we may accept the premise that our future oil reserve is a much more predictable quantity than the "possible" ore reserves of the metals.

The terms "proved" and "probable," as used to differentiate ore reserves, have less distinctive meanings when used to classify oil reserves, because of the association of oil with certain controlling geological environments or structures. These limiting features are measurable in some degree and generally afford good indications of volumetric oil con-

tent once the characteristics of the oil reservoir have been determined. Strictly speaking, a proved oil reserve might be regarded as only the oil certain to be recovered from existing wells. Such definition, though influencing some of the early thought on the subject, is considered a very defective measure for employment in weighing the broader economic considerations. Recent commentators, including Pogue, Pratt, Heroy, the writer, and others, in considering national problems, are inclined to extend the term "proved oil reserve" to mean "the reasonably probable quantity of oil that can be economically recovered by existing methods from proved oil-bearing structures or fields."

In estimates conforming to this definition, the only factor definitely proved is the existence of the field; the quantity of oil reserve being a collateral probability. Nevertheless, it may be stated with confidence that this definition affords a workable common base from which a rational orientation of the entire subject may be projected.

A chronological breakdown of the national oil reserves correlated with the periods corresponding to the discovery thereof is believed to have first made its appearance in the published literature in an article by Wallace Pratt¹ in 1935. The time unit selected by Pratt was a five-year period, and the illustrative figures presented were dated from the time that oil was discovered in Pennsylvania in 1859. The writer, in 1934, completed the compilation of an estimate of domestic reserve discoveries by individual years beginning with 1920. These figures were based on an adjustment of the estimated Dec. 31, 1919, reserve to reflect the estimated annual discoveries subsequent thereto.

Revised and brought up to the end of 1936, the author's compilation of annual new discoveries is presented in Table 1. The term "discovery" as used includes important lateral extension of fields beyond the recognized limits of a given time; and the proving up of deeper productive horizons. The last column gives the time supply measurement of the estimated reserves at the end of each year in terms of years' capacity to sustain estimated future² consumption. Determination of this relationship involves the summation of cumulative future production from the end of a given year to the time at which it equals the estimated reserve at the end of the selected year. Thus it was found that the estimated known reserve as of Dec. 31, 1920 (7,676,000,000 bbl.) was balanced by a production of like amount accumulated at the end of 10.4 years, or, say, in April 1930. For the earlier years of this period up to 1926, actual production figures were used in this time computation. For the more recent years since 1926, the accumulated production to

¹ W. Pratt: Oil Production—Analysis of Its Development and Stabilization. *Oil & Gas Jnl.* (May 2, 1935).

² The actual figures are for domestic production, which in effect is equivalent to consumption of underground reserve.

the end of 1936 fell short of balancing the indicated reserve at the end of any given year. This necessitated a projection of the accumulated production beyond 1936, which, in the figures herein presented, was extended into the future on the basis of an assumed constant 3 per cent increase in the annual rate of production over each preceding year. This might appear to be a low rate of increase in the light of the record of recent years, but is not out of line with the average for the past decade. Considering the trend toward more efficient utilization of motor fuel, a conservative long-term viewpoint bearing on the increase in annual rate of consumption is necessary.

TABLE 1.—*Estimated New Reserve Discoveries*
BARRELS

Year	Estimated Reserve Discoveries	Domestic Production	Estimated Net Reserve Change	Estimated Total Proved Reserve at End of Year	Estimated Year's Supply
1919				7,534,000	10.4
1920	585,000	443,000	+ 142,000	7,676,000	9.9
1921	800,000	472,000	+ 328,000	8,004,000	9.9
1922	800,000	557,000	+ 243,000	8,247,000	9.9
1923	800,000	732,000	+ 68,000	8,315,000	9.8
1924	800,000	714,000	+ 86,000	8,401,000	9.9
1925	810,000	764,000	+ 46,000	8,447,000	9.5
1926	1,547,000	771,000	+ 776,000	9,223,000	10.0
1927	1,353,000	901,000	+ 452,000	9,675,000	10.2
1928	1,936,000	901,000	+1,035,000	10,710,000	10.8
1929	1,100,000	1,007,000	+ 93,000	10,803,000	10.8
1930	4,000,000	898,000	+3,102,000	13,905,000	12.9
1931	517,000	851,000	- 334,000	13,571,000	12.5
1932	1,030,000	785,000	+ 245,000	13,816,000	12.1
1933	500,000	906,000	- 406,000	13,410,000	11.5
1934	700,000	908,000	- 208,000	13,202,000	10.9
1935	1,400,000	994,000	- 406,000	13,608,000	10.8
1936	900,000	1,073,000	- 173,000	13,435,000	10.5

The utility of this form of close chronological analysis is further indicated by the graph, Fig. 1, which illustrates the foregoing text and the manner in which projected estimates of future year-end reserve positions can be visualized. The six-year end reserve positions figured for future years beyond 1936 are based on an arbitrary assumption that the annual rate of reserve replenishment will continue at the rate estimated by the writer for 1936; i.e., 900,000,000 bbl. There is no presumption, of course, that this will be the actual average rate of discovery over the next six years; and the resultant effects of a wide range of discovery rates would be of interest to a comprehensive investigation. Consumption, it is assumed, will maintain the average 3 per cent annual increase previously referred to. Here, also, the effect of varying consumption

rates in combination with varying rates of discovery is of interest to a complete study of the subject.

It will be evident to all students of the subject that to a considerable degree the graph should be regarded as merely diagrammatic. The starting point—that is, the figure for the proved oil reserve at the end of 1919—and likewise the discovery accomplishments of the earlier years can be retroactively estimated at this time more accurately than was

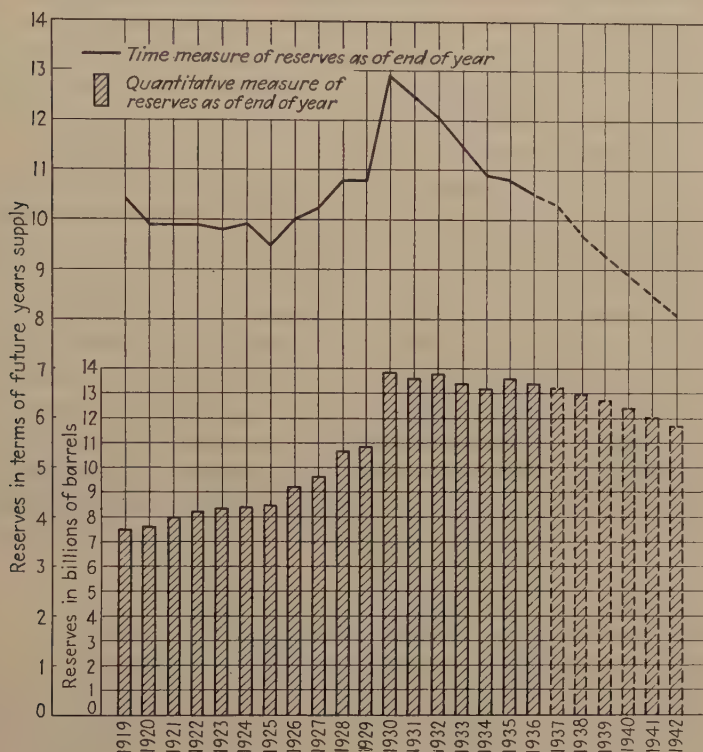


FIG. 1.—GRAPHIC REPRESENTATION OF PAST DOMESTIC OIL RESERVE CHANGES AND ESTIMATED FUTURE CHANGES BASED ON MAINTENANCE OF 1936 RATE OF NEW DISCOVERIES AND AN ASSUMED 3 PER CENT ANNUAL INCREASE IN CONSUMPTION REQUIREMENTS.

possible to forecast them in the contemporaneous estimates of corresponding periods. In general, however, the degree of accuracy diminishes as one approaches the present, and obviously the estimates for the last few years are built up on recent discoveries, with corresponding quantity factors of a conjectural nature. A further but minor complication arises in many instances from the difficulty in determining the year to which a given discovery should be credited. This is largely a matter of opinion according to the viewpoint of the investigator, since frequently the data are open to various interpretations.

Subject, however, to its mentioned limitations, it is believed that the graph objectively portrays the important relationships. It will be observed that whereas the reserve itself may be maintained at a relatively constant volumetric quantity, its adequacy in terms of future years' supply may be rather sharply diminishing as a result of a steadily increasing consumption. Though not specifically indicated by the graph, the following simple inference may be readily derived therefrom:

To maintain a given time measurement of reserve against an increasing production trend, the annual reserve replenishment must *exceed* contemporary consumption. In fact, it must equal the estimated consumption at the end of the given time period corresponding to the reserve measurement, in this case $10\frac{1}{2}$ years.

As an illustration, the 3 per cent secular increase in consumption here assumed implies a consumption in 1946 some 34 per cent above that of 1936. Thus, to hold the same $10\frac{1}{2}$ -year time reserve, the discoveries in the current year must be equivalent, not to contemporary consumption but to the 34 per cent greater consumption expected in 1946. Or, looking in retrospect at the 1936 results, we observe that though production (consumption of reserves) was approximately 1,100,000,000 bbl. in 1936, our discoveries in that year, if sufficient to maintain a $10\frac{1}{2}$ -year reserve, should have been 34 per cent greater than production, or approximately 1,482,000,000 bbl. The actual discoveries in the past year probably fell below 900,000,000 bbl., thus creating a much sharper shrinkage of known national reserve in terms of time supply than would be indicated by a superficial comparison with the volume of 1936 production alone.

The steady drop in effective time reserve that has taken place since 1930, and the imminent further contraction that seemingly can be arrested only by a rate of annual discovery substantially in excess of the average rate that has prevailed heretofore, points to the conclusion that an intensified activity in oil exploration must follow as a natural consequence if reserve replenishment is to maintain the existing indicated time supply.

A collateral consideration has to do with the price of crude oil and refined products, which may be expected to economically support the increased exploration expenditure that may be required—provided our national requirements are to be met exclusively with domestically produced oil. If the results of 1936, a year of relatively high exploration activity, are taken as a criterion, there is reason to believe that exploration activity, in order to be adequate for national requirements, may require the stimulus of higher price levels for the products of the industry.

The long-term trend of future oil requirements, which is of the utmost importance in the time measurement of reserves, is, of course, determined by changing influences. Consequently, it is essential that a projection

of the type discussed here be regarded as probable only in relation to the accuracy of estimates of future consumption.

An increase in consumption is indicated by such factors as the probable continued growth of population; ever higher standards of living; the rapidly growing use of oil for heating; Diesel-engine developments, and the growth of aviation. On the other hand, developments in the direction of increased motor efficiency, and the introduction of new refining processes such as hydrogenation, polymerization, etc., suggest a decreasing demand on our petroleum reserves for a given requirement of energy. The writer's consideration of these factors and others leads him to the belief that a 3 per cent average annual increase in consumption for the next decade is at least a reasonable and probably somewhat conservative assumption.

Oil, like other commodities, however, must be considered as subject to the inherently unpredictable factors that influence demand. Accordingly, frequent revisions of any projection into the future will be necessary. Thus the data and graphic portrayal herein presented cannot be an unqualified prediction of future annual consumption and corresponding annual need for replenishment. Rather, it illustrates a simple method whereby the investigator, by applying his own estimates of increased consumption for the future, may more accurately gauge the magnitude of exploratory effort necessary to convert the "possible" but undiscovered reserve of the nation into the "probable" and "proved" classifications.

Role of Price in the Functioning of Proration

BY JOSEPH E. POGUE,* MEMBER A.I.M.E.

(New York Meeting, February, 1937)

PRICE is a complicated concept, for price is both a cause and an effect. This reciprocal aspect is commonly overlooked and the oversight is the source of many economic maladjustments. Price is the resultant of the ratio between supply and demand, but it differs from a mathematical concept of a proportion, by itself constituting an economic force which continuously alters the elements that determine the relationship. Price, therefore, is not merely the outcome of other forces but is in its own right one of the most powerful of economic agents. Price accordingly does not play a passive role; nor can it be sterilized or rendered inactive. In consequence, price cannot be fixed or at least kept fixed, except by the elimination of all freedom of choice on the part of producers and consumers.

A primary objective of all economic activity is equilibrium. The same is true of a unit of economic activity, the single industry. The plane upon which equilibrium centers may shift in the course of time, but equilibrium itself is the point of departure and the point of return. If an industry is in equilibrium, that industry is operating effectively. The motivating forces of an industry—profits or the common good—are not to be confused with the prerequisite of equilibrium, but this mistake is often made. The producer is dominated by the profit motive; the consumer, or his collective representative, by the general welfare motive. No one is the advocate for equilibrium; that status is supposed to be arrived at automatically. If the forces of competition are perfectly free, such is the tendency.

EQUILIBRIUM

For the purposes of this analysis, equilibrium needs to be broadly defined and is conceived to involve: (1) balance between supply and demand; (2) internal equipoise amongst the elements within an industry; and (3) symmetry in respect to the whole economy. This definition implies flexibility and ease of adjustment; a ready accommodation to change. Equilibrium does not postulate profits or nonprofits, social objectives or the lack of them. A decadent industry may be in equilib-

Manuscript received at the office of the Institute Feb. 1, 1937.

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rium, but nonprofitable; such an industry cannot be made profitable except through subsidy, which is a violation of equilibrium.

What are the means for maintaining equilibrium? In a freely competitive economy, there is only one: price. In a semicompetitive economy, such as that under which we are now living, there are two: price and regulation of supply¹. In an activity such as the American petroleum industry, in which competition is highly developed but yet is modified by proration in the production of crude oil, our problem is to determine the proper function of price: to what extent its status has been modified by the introduction of retarded supply into the equation. For this purpose, we need a clear understanding of the nature of proration.

PRORATION

Proration is itself a complicated concept, because it is a compound or dual affair. It is at once a measure for minimizing waste and a regulator of supply, or a production control. Its legal authority is derived from its conservation function; its production-control aspect is a pragmatic adjustment to the exigencies of the occasion. The technical and human factors involved require, or have seemed to require, a balancing of supply and demand to achieve a minimizing of waste. Theoretically the conservation aspect could function alone, through the expedient of limiting each field to its optimum rate, competition freely ruling in all other respects; but practically proration has developed and become institutionalized, with the added accompaniment of such regulation of supply as to balance supply and demand. It may be perceived that this appended element is a resultant of potential overproduction, perhaps merely a temporary or recurring item in the mechanism; one that will be minimized or even eliminated in event of demand exceeding the *efficient* rate of production of the resource. Thus proration may be expected to vary in structure or degree of application at different phases of the oil cycle.

Proration is not thought to be an invention or device planned to meet a specific set of conditions, but an evolutionary mechanism born of necessity. It came into existence in institutionalized form when the rule of capture was rendered untenable by accumulating overproduction under the stimulus of advancing technology in oil finding and production. Once the momentum of supply came to exceed the capacity of demand to absorb the output, the stimulus of the rule of capture became insupportable and suffered modification. This modification was effected by means of a regulatory mechanism which we call proration. In short, under the conditions outlined, price alone proved incapable of maintaining equilibrium and the institution of proration arose to help meet the issue. The

¹ In the monetary field some experiments in the regulation of demand are being witnessed.

production-control aspect of proration is necessary, or at least convenient, only in a supply-dominated cycle; the conservation aspect of proration is desirable not only there but in a demand-dominated phase as well. The lasting achievement of proration is its conservation function, which has become thoroughly grounded in practice and procedure and basically integrated into the economic structure of the industry.

FUNCTIONS OF PRICE

The principal functions of price, in a freely competitive industry, are: (1) to equate supply and demand by retarding or accelerating the rate of change in each of these two elements; (2) to allocate the component parts of supply and demand to one another; (3) to regulate the movement of capital into and out of the industry. Proration, operating as a combined production-control and conservation measure, serves to relieve price of part of its functional responsibility, but by no means supplants price in its essential role. Price is merely modified as an instrumentality for the maintenance of equilibrium; and the degree of alteration appears upon careful analysis to be superficial rather than fundamental.

Price, in the presence of proration, is relieved of the responsibility of equating supply and demand, and to some degree of allocating the component parts of supply and demand to one another. Price, however, is left unmodified in its effect upon drilling and search, upon the movements of capital involved in those activities, upon demand and the attraction or repulsion of buying power. Therefore, with proration operating, price continues as an effective causal agent, but with its power rendered less immediate. Thus a rigidity is introduced into the price structure, because the functional incidence of price on the supply side of the equation is moved from the surface to a deeper level, involving a greater lapse of time between cause and effect; but the influence of price is thereby unbroken: merely its time gradient is altered. This deepening of the plane upon which price operates is apt to create the belief that price has been divorced from its usual economic consequences, but as a matter of fact price will continue to manifest itself functionally but more slowly. For this reason any attempt to utilize the machinery of proration for price-fixing purposes (i.e., for creating price levels out of line with prevailing economic conditions) is doomed to failure.

The mechanism used to arrive at the prevailing price for crude petroleum is more or less unique among commodities. The existence of integrated pipe-line systems renders central markets impracticable and in effect brings the crude-oil market to the innumerable points of production. While the price level must be determined in the long run by the economic forces at work, the buyers of crude oil have the responsibility of nominating the prevailing price level, and of naming a higher or lower bid price

at such periods as conditions seem to call for a change. When one important buyer posts a new price, competition tends to bring about conformance on the part of all other buyers, provided the new bid is soundly conceived, otherwise the initial change turns out to be a false move. In this way the price of crude oil is arrived at by a process of trial and error, which is the method of central markets where buyers and sellers come together in innumerable small transactions. The nature of the procedure, however, tends to create the illusion that prices are established by buyers, whereas they are only named by buyers; and this view is apt to be heightened by tendencies to personify economic forces, especially in an industry so individualistic and personal as that of petroleum.

If it be accepted that industrial equilibrium is a *sine qua non* and that a primary purpose of price is to contribute to that end, what then should be the reasoning of the buyer when he names a price? The following principles may be listed for consideration:

1. The price should be designed to bring forth the supply properly needed.

2. The price should provide the degree of stimulus for exploration that seems appropriate in light of the prevailing discovery rate, potential production, and oils in storage.

3. The price should not normally be out of line with the realization obtainable from a barrel of crude.

4. The price should not be such as improperly to retard or accelerate demand, the meaning of "improperly" varying at different phases of the cycle.

5. The price should bear such relation to cost as to promise a proper flow of capital to and from the industry².

It will be immediately observed that the criteria outlined are general and are not subject to precise determination. Furthermore, several of them involve future considerations. Quite so; and this is the reason why price nominations must be experimental and the price structure itself left free to back and fill to arrive at an equilibrium level. It will be observed, further, that these criteria do not differ substantially from those that would appear desirable under nonproration. True, again, but the following important qualification should be held in mind. Proration has contributed a rigidity to the price structure and an attitude of mind regarding its alteration, that are working against the functional manifestation of price; and this development presents a twofold liability: (1) in the event of overdiscovery, the way is left open for the development of

² The fulfillment of these criteria may fail to insure an equilibrium rate of drilling. To obtain balance in respect to this item, the machinery of proration should be so directed as to normalize, rather than overstimulate, the drilling of known fields. See J. E. Pogue: *The Role of Drilling in the Functioning of Proration*. *Trans. A.I.M.E.* (1936) **118**, 195-201.

sustained drilling campaigns leading to the loss of equilibrium; (2) in the event of underdiscovery or of inflationary demand, the way is left open for the inhibition of the price changes needed to facilitate transition to a new plane of equilibrium. In short, the petroleum industry, now as well as formerly, stands in need of a flexible price structure attuned to directing the forces of price to the safeguarding of equilibrium.

Various Aspects of Oil-stock Prices

BY GEORGE W. DOFFING*

(New York Meeting, February, 1937)

NUMEROUS contradictory statements have been made in the past regarding the importance of the seasonal influence of demand for motor fuel on prices of oil securities. It has often been said that the time to buy oil securities is in the spring, or just prior to the heavy consuming season for gasoline. The fallacy of this argument is brought out in the following paragraphs.

SEASONALITY OF OIL-SECURITY PRICES

The indexes used in this paper as indicators of prices of oil securities and general industrials are those compiled by Standard Statistics Co. The oil producing and refining stock index includes 14 representative petroleum companies, while the all-industrials index is made up of 347 issues. All figures are stated as relatives, with 1926 = 100.

The primary basis of the index, and one that gives a good weighting of the relative importance of the company within the industry, is the total market value of the stock issue outstanding; i.e., the market price times the number of shares outstanding. Adjustments are made for the addition or elimination of issues from the group index, for stock dividends, split-ups, stock rights, et cetera.

At the present time the oil producing and refining index includes the following companies: Atlantic Refining Co., Consolidated Oil Corporation, Continental Oil Co., Gulf Oil Corporation, Humble Oil & Refining Co., Ohio Oil Co., Royal Dutch Co., Shell Union Oil Corporation, Socony-Vacuum Oil Co., Standard Oil Company of California, Standard Oil Co. (Indiana), Standard Oil Co. (New Jersey), Texas Corporation, Union Oil Company of California.

In calculating the seasonal for oil-security prices several periods have been selected as indicative of major changes in the industry, as follows:

1. 1918 through 1936. This gives an over-all picture of the industry during the motor-vehicle, motor-fuel era.

2. 1927 through 1936. This period includes the control stages, both voluntary and coercive.

3. 1927 to September, 1933. This is the pre-code period of control.

Manuscript received at the office of the Institute Jan. 28, 1937.

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4. September, 1933, through 1936. This includes the N.R.A. code era and the post-code stage, involving cooperation of federal and state administration.

In order to eliminate the general market factor in the oil-stock index, the latter is expressed as a ratio to the all-industrial stocks index. The seasonal of the adjusted oil producing and refining stocks index is then computed by the link relative method, as devised by Warren M. Persons¹.

TABLE 1.—*Seasonal Index for Oil Producing and Refining Stocks*
(O. P. & R. index expressed as a ratio to the All Industrials index) — 1926 = 100

	A	B	C	D
	1918-1936	1927-1936	1927- Aug., 1933	Sept., 1933-1936
January.....	102	100	100	100
February.....	101	99	99	101
March.....	100	99	98	101
April.....	99	99	99	99
May.....	100	100	99	101
June.....	100	101	101	101
July.....	99	101	102	99
August.....	98	100	100	99
September.....	98	98	98	98
October.....	99	99	98	99
November.....	102	102	104	101
December.....	102	102	102	101

The striking feature of these seasonal calculations is the *lack* of seasonal. Except for the month of November in the period of 1927 to August 1933, the greatest variation above or below 100 for any month is only 2 per cent, or negligible in amount. Consequently, the desire of investors to time their purchases or sales of oil securities on the basis of seasonal high or low spots is rather a hopeless one. To go one step further, a seasonal index for oil stocks, uncorrected for the market, has

TABLE 2.—*Seasonal Index for Oil Producing and Refining Stocks,*
1927-1936
(1926 = 100)

January.....	101	July.....	100
February.....	100	August.....	101
March.....	99	September.....	100
April.....	102	October.....	97
May.....	100	November.....	101
June.....	98	December.....	101

¹ E. E. Day: Statistical Analysis.

been calculated for the 1927-1936 period, or that of voluntary and coercive control (Table 2).

A comparison of Table 2 with column B of Table 1 shows that the principal difference is a shift in emphasis for the various months involved, especially April and June, which show a change of three points between the two indexes.

It is concluded, therefore, that no significant seasonal variation exists for oil-security market prices. To further amplify this deduction, and to more fully eliminate the fallacy of relationship between demand and market price, a study of the correlation between demand and oil-security prices has been made.

RELATIONSHIP BETWEEN DEMAND FOR OIL PRODUCTS AND MARKET PRICE OF OIL SECURITIES

For this comparison three relationships have been computed:

1. Oil-security prices with domestic demand for motor fuel.
2. Oil-security prices with domestic demand for all refined oil products.
3. Oil-security prices with the dollar value of domestic motor-fuel demand.

The Standard Statistics index of oil-security prices is used in these comparisons, while the demand figures are those compiled by the Bureau of Mines. The dollar value of domestic motor-fuel demand is obtained by multiplying the monthly demand figure by the average tank-wagon price (ex tax) for gasoline in 50 representative cities. All data are related to 1926 as 100.

By the use of dispersion charts, a natural segregation of the data into two periods was indicated; or 1918 to 1927 inclusive, and 1928 through 1936. In the first period, that of mushroom growth, the correlation coefficients² were under 0.5 for all three comparisons, or inconclusive. For the second period, from 1928 onward, the lack of relationship between domestic motor-fuel demand and oil-security prices was so evident on a dispersion chart as to preclude further consideration. This is obvious, also, from the known importance of price on industry profits. Similarly, no relationship existed between security prices and total demand for all oils.

However, the dispersion chart on the relationship of oil-security prices with the dollar value of motor-fuel demand showed some possibility of correlation and warranted a lag study of the data. On a direct month-to-month comparison the correlation coefficient was 0.73, or definitely inconclusive; so calculations were made on the basis of one, two, three and four months lag of security prices with the dollar value of motor-fuel demand.

² L. P. Ayres' method of correlation used. See E. E. Day: Statistical Analysis.

Certain definite limitations of the data used might be stated at this point. Domestic motor-fuel demand is not actually consumer consumption but really refinery demand based on refinery production, imports, exports and changes in refinery and pipe-line inventories. However, this demand figure is the only one available and is probably fairly indicative of actual consumption. In addition, the gasoline-price index used is merely an average unweighted figure of state prices, with the assumption that the major city in the state is fairly indicative of the state-wide price situation. Naturally, the smaller states are weighted too heavily and the more populous areas insufficiently. However, the use of 50 prices should give a fairly good sample for the country as a whole.

Another limiting factor is the delay in publishing the data on motor-fuel demand. These figures are usually reported from five to six weeks after the end of the month in question.

Using one, two, three and four months lag of the oil-security price index to the dollar value of motor-fuel demand, the following coefficients of correlation were obtained:

	COEFFICIENT OF CORRELATION
No lag.....	0.73
One month lag.....	0.66
Two months lag.....	0.68
Three months lag.....	0.61
Four months lag.....	0.58

In other words, the direct month-to-month relationship was the most favorable, though decidedly inconclusive and of little practical value, since the data are not available until five to six weeks after the end of the month in question.

To complete the study, a reverse lag was calculated; i.e., a lag of the dollar value of domestic motor-fuel demand in relation to the oil-security index:

	COEFFICIENT OF CORRELATION
No lag.....	0.73
Two months lag.....	0.75
Four months lag.....	0.70

The small improvement in this correlation is logical in view of the tendency of stock-market prices to forecast developments in industry. However, the indicated correlation is still poor and further bears out the thesis that demand in the oil industry is not the major determinant in the movement of oil-security prices and, consequently, offers the explanation for the lack of seasonal variation in the oil-security index. It has been shown that: (1) demand alone has practically no effect whatever on oil-security prices; and (2) that motor-fuel demand, even though

adjusted for price, has little correlation with the oil-stock index. While a comparison of the dollar value of the demand for all refined products with the oil-security index would be a more conclusive determinant of the demand factor on oil prices, the use of motor fuel alone is an adequate sample owing to the importance of this product in terms of dollar realization for all refined products. In addition, the trade and the market generally determine the progress of the oil industry on the basis of the gasoline situation.

It is not within the scope of this report to consider the relationship of prices or refinery realization margins, by themselves, to the movement of oil-security prices. An excellent paper (unpublished) was read by Dr. Norman Fitzgerald at the A.I.M.E. meeting in February 1935, on the relationship of spot gasoline prices to oil-security prices; and an illuminating article by William H. Garbade, Jr., was published in *The Annalist* (Jan. 1, 1937), comparing the refinery return (adjusted for refinery cost for integrated units) for crude oil (Middle West area) with quarterly net income of a group of oil companies, and also net income with oil-stock prices. The principal conclusions that can be drawn from the various studies are that oil-security prices tend to reflect total refinery margins to a greater degree than actual dollar realization from the principal product, motor fuel, and that demand, by itself, is a minor causation of changes in market quotations.

MOVEMENT OF OIL-SECURITY PRICES

In previous paragraphs the principal stress has been on short-period security fluctuations as a reflection of the products situation. For an investor the long-range point of view is of equal or greater moment, especially in terms of the influence of raw materials.

On Fig. 1 the oil-security index is compared with the movement of all industrials. The four lines on the chart are made up of the all-industrial index, the oil index, the all-industrial index as 100, and the ratio of the oil index to the all-industrial index as 100. Inasmuch as general market fluctuations present a strong impetus to individual group movements, changes in oil-security prices as a ratio to all industrials should present the truest picture of actual conditions. As shown on the chart, the adjusted oil index dipped gradually in 1919 and early 1920, rose sharply to late 1920, remained fairly steady to early 1923, and then began a long decline which lasted until early 1929, with a small recovery in the first half of 1930, followed by a sharp break until May 1931, another substantial recovery to July 1932, a sharp break to August 1933, a recovery to November 1933, and then an oscillating downward movement to October 1935. Since that time the adjusted index has been at slightly higher levels.

These wide swings in the adjusted index will be viewed on the basis of four main factors: crude-oil discoveries, flush production, crude prices and inventory changes. No attempt is made to belittle demand, but it is believed that the supply factor has been the difficulty in one way or another throughout the period. It might be mentioned that demand for all oils increased almost without interruption from 1918 through 1929, or a total of 158 per cent; declined only 15 per cent from 1929 to 1932; and again advanced 26 per cent from 1932 through 1936. Table 3 shows a rough compilation of crude-oil reserves over the period 1918 to 1936.

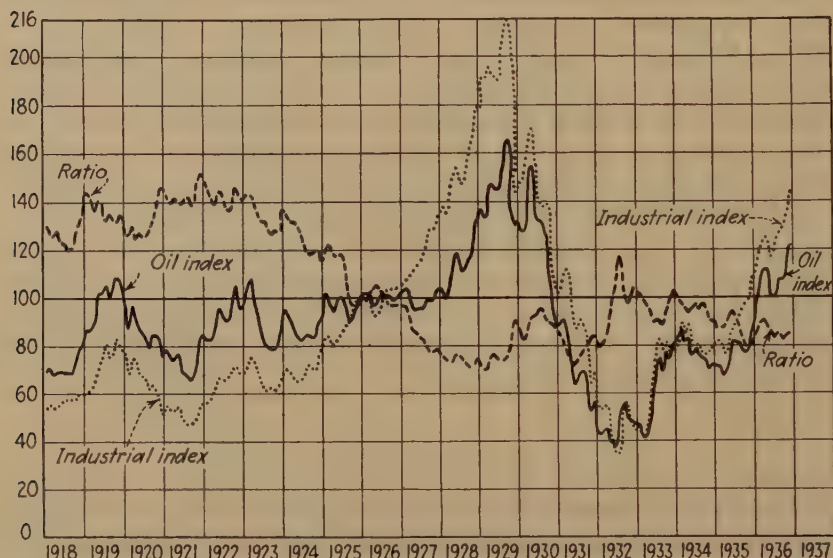


FIG. 1.—RATIO OF INDEX OF OIL PRODUCTION AND REFINING TO INDEX OF INDUSTRIAL STOCKS.

Source: Standard Statistics Co., oil index 14 stocks, industrial index 347.

On the basis of accumulated crude-oil production of 18,680 million barrels by Dec. 31, 1936 (1936 output estimated at 1090 million barrels), and accumulated reserves of 31,200 million barrels to the same date, outstanding proven crude reserves at the end of 1936 would have approximated 12,520 million barrels.

Flush production from the leading pool discoveries since 1918 has been calculated from data reported in the *Petroleum World—Annual Review of the California Oil Industry*; *Minerals Yearbook* and the *Oil and Gas Journal Annual Reviews*. The year of flush production does not necessarily coincide with the year of discovery; for example, East Texas was discovered late in 1930 and only reached important producing levels in 1931, while Ventura Avenue was found in 1916 but did not attain real flush output until 1923. As a matter of simplification, flush output will

TABLE 3.—*Crude-oil Reserve Discoveries and Accumulations, and New Flush Production in Relation to Domestic Output*

Year	Discoveries ^a , Millions of Barrels	Accumulated ^a , Millions of Barrels	New Flush Production as a Percentage of Domestic Output ^b , Per Cent
1918	350	10,750	1.9
1919	700	11,450	2.4
1920	900	12,350	7.9
1921	1,100	13,450	4.3
1922	1,000	14,450	10.7
1923	650	15,100	10.8
1924	600	15,700	4.0
1925	900	16,600	8.2
1926	1,600	18,200	10.3
1927	900	19,100	16.6
1928	3,000	22,100	1.2
1929	1,500	23,600	4.0
1930	3,000	26,600	4.9
1931	1,100	27,700	12.7
1932	300	28,000	0.9
1933	250	28,250	0.6
1934	650	28,900	1.1
1935	1,500 ^c	30,400	0.9
1936	800 ^c	31,200	

^a "American Petroleum Industry—1935"—American Petroleum Institute.

^b Mineral Resources of the United States; Minerals Yearbook; Oil and Gas Journal—Annual Reviews.

^c Estimated by writer.

be stated as a percentage of total domestic production for the years in question.

During the first significant period of market-price movement for the adjusted oil-security index (expressed as a ratio to the all-industrial index), or the decline from early 1919 to July 1920, crude discoveries were fairly large in relation to actual output; flush production from such leading pools as Hull and West Columbia, Texas, Richfield and Elk Hills, Calif., and Hewitt and Burbank, Okla., increased considerably from 2 per cent of the domestic total in 1918 to 8 per cent in 1920; while inventories of all oils showed a declining tendency in terms of days' supply, or from 163 in 1918 to 154 in 1920. However, while discoveries were large and flush production increasing, settled output declined and demand was favorable. With these contradictory influences at work, crude prices rose from \$2.25 per barrel in 1919 to \$3.50 in 1920, while the adjusted oil index declined as a reflection of the uncertainty engendered by the new reserve discoveries. However, the situation improved in the latter part of 1920, and the adjusted index rose fairly sharply.

Further heavy discoveries in 1921, a halt in the demand increase during the 1920-1921 depression, and an advance of 46 days' supply for inventories finally caused a price reaction from \$3.50 to \$1.00 per barrel. Nevertheless, these factors had been fairly well discounted in 1920, so that the adjusted oil index was fairly well maintained. In 1922 and 1923 discoveries were fairly heavy, flush production totaled around 11 per cent of domestic output in both years, and inventories began to accumulate rapidly despite a large increase in demand. Consequently, crude prices were jittery, dropping from a high of \$2.25 in June 1922, to a low of \$1.02 in December 1923. As a consequence, the adjusted oil-security index declined substantially.

In the latter part of 1923 and in 1924, crude discoveries fell off considerably from earlier periods, the only major new pools in 1924 being Luling, Dominguez, and Cromwell. Consequently, flush production dropped to around 4 per cent of domestic output, inventories remained unchanged in days' supply, and demand continued its upward trend. However, the adjusted oil index declined during the year 1924, owing to the fact that industrials progressed even more rapidly than the actual oil index.

Over the next three years, 1925-1927 inclusive, new pool discoveries came in at an increasing pace, and the adjusted oil index dropped precipitously. In this period were found such areas as Inglewood and Seal Beach, in California; Big Lake, Spindletop (revival), Panhandle, Yates, Hendricks, and Upton-Crane in Texas; Wewoka, Seminole City, St. Louis-Pearson, Earlsboro, Bowlegs, and Searight, Oklahoma; Sunburst, Montana; and Sumner County pools, Kansas. Flush production rose from 8 per cent of the national total in 1925 to around 16.5 per cent in 1927. Inventories remained at high levels despite an excellent consumption growth, and crude prices dropped to around \$1.20 per barrel after a recovery to \$2.25 in 1926. In the latter year, the adjusted oil index did fairly well, since the major portion of new discoveries, totaling 1600 million barrels, was not found until late in the year, and inventories showed a decline for a change.

As a result of the increasing tendency to hasten production from newly found areas, the industry attempted to solve the situation by voluntary proration of output, and a fairly good measure of success was obtained up to the coincidence of several factors late in 1930; namely, the depression, the discovery of East Texas, and the first decline in total demand for all oils since 1921.

The period from November 1930 to September 1933 is undoubtedly still vividly etched in the minds of all who have followed the fortunes of the oil industry and can be expressed in two words: East Texas. Of total domestic crude-oil output in 1931, 1932 and 1933, East Texas alone furnished 12.6, 15.5 and 22.4 per cent, respectively. Various attempts

were made to get the field under control, but most of them proved ineffective until state action was supplemented by the N.R.A. code late in 1933, and the bitter experience of 10-cent crude touched the pocket-book of the individual producer. The temporary recovery of the oil index late in 1931 and the first half of 1932 was largely due to the arbitrary shutdown of the field for several weeks by the Governor of Texas; Sunday holidays for production from November 1931 to February 1932; the passage of a conservation law by the state of Texas, which included market demand with economic waste; and the decision of the United States Supreme Court in the Champlin case, affirming the power of the State of Oklahoma to regulate production of crude oil under its conservation statute.

The period 1934-1936, inclusive, witnessed the emergence of a new phase in the oil industry—coercive control. In this period, despite crude discoveries of 650 million barrels in 1934, of 1500 million barrels in 1935 and 800 million barrels in 1936, flush production from new areas was at low levels, the most important being Rodessa, which accounted for around 2.2 per cent of the national total in 1936.

The year 1934 may be designated as the test, or "injunction," period of control, especially in respect to the federal phase as represented by Section 9C of the N.I.R.A. Uncertainty was the prevailing note relative to legality of federal control of production and in regard to the ability of the Texas Railroad Commission to police effectively the 125,000-acre East Texas field. Consequently, adjusted oil-security prices manifested a sagging tendency throughout the year, despite an appreciable decline in inventories of all oils, low crude-oil discoveries and small new flush production.

The year 1935 marked the transition from illegal emergency regulation to a system of state and federal cooperation, which probably will be a permanent and integral part of the oil industry. Further improvement occurred in the statistical position of the industry with all oil inventories off a 21 days supply, demand at a new high level, and flush production from new fields of little consequence. However, adjusted oil-security prices fell off as a reflection of two severe shocks, the invalidation of Section 9C of the N.I.R.A. on Jan. 7, 1935, and of the N.I.R.A. itself on May 27, 1935. As a result of the latter decision, the Pacific Coast Agency Agreement became null and void, leaving California without any legal force to regulate production. The second half of 1935, therefore, was one of overproduction and declining prices on the Pacific Coast, which, naturally, had a dampening influence on oil securities generally.

In 1936 crude prices were raised from 10¢ to 15¢ per barrel early in January, which was followed by a substantial improvement in the adjusted oil-security index. However, new flush production from

Rodessa and rapid increases in gasoline inventories injected new doubt and uncertainty into the situation, and the oil-security index again declined. Fortunately, demand was extremely favorable, Louisiana entered the link of control, new discoveries were well below production, and all oil inventories were cut another 23 million barrels to the lowest level since 1926. As a consequence, the adjusted oil security index gradually rose to higher levels by the end of the year.

SUMMARY

The discussion in the previous paragraphs has been an attempt to show the peculiar nature of the oil industry; i.e., the extreme importance of a check on new supplies. Oil is a migratory raw material, the ownership of which is not legally effective until it is brought to the surface. When discoveries were heavy, large amounts of new flush production naturally pressed upon the market and broke prices to levels below production costs. Since 1927 efforts have been directed toward a rationalization of this phenomenon, originally by voluntary action and finally by coercive state and Federal control.

Since 1931 the problems involved in such coercive regulation have been tests of the legality of control legislation, improvements in the mechanics of control, and education of the interested parties to control. These include the producer, the leaseholder, the governmental agencies, and the public. Fortunately, the control theory has been aided by natural phenomena in the industry itself, including such developments as increased concentration of wildcat acreage in the hands of the larger units, a greater percentage of wildcat drilling by these same companies, and higher costs for wildcatting and exploration.

While it is realized that discoveries have not been particularly heavy since 1931, flush production outside of East Texas has been smaller in relation to national output than normally would have been the case, partly because of more effective control and of greater concentration of ownership of new areas in strong hands. No illusion is held that the present control system is perfect by any means, but improvement in method, participation, and effectiveness has been encouraging. It might even be said that the oil industry is "coming of age."

Future Demand for California Petroleum Products

BY A. H. HAND*

(Los Angeles Meeting, October, 1936)

WHEN considering the question of future demand for crude petroleum in California, one must first decide whether it is to be approached in the light of the definition of "demand" when used in economics; i.e., "The quantity of any commodity required or sought in the market," or in the light of markets developed to dispose of total supply. Therefore, is the California demand of future years to be predicated on a continuation of supplying markets developed following the surplus production commencing in 1922, or predicated on supplying what would be termed economic markets? If the latter, what are economic markets?

Obviously, the Pacific Coast States and Canada, Alaska, Hawaii and probably the Pacific side of Central and South America, can be considered as normal markets for California petroleum products. While there have been small quantities of gasoline shipped into the Pacific Coast from East Texas, transportation costs, plus import taxes in the case of foreign oil, are a sufficient barrier to justify considering that these markets will be retained.

But how about our participation in Atlantic and Pacific foreign and intercoastal markets? During the five years preceding 1931 California shipped substantial quantities of gasoline to the United Kingdom and to France, Germany and Italy. During recent years our business in European markets has been restricted to occasional shipments of gasoline and Kettleman crude. This loss of business is occasioned by the development of production in the Mid-Continent, principally East Texas, and in Iraq, Rumania, Venezuela and other closer producing areas, which makes it impossible at the prevailing crude-oil prices for California to be competitive in supplying any substantial portion of these markets. It is therefore apparent that under a stabilized price structure that will return the California producer a reasonable price for his oil, future Atlantic foreign business will be restricted to occasional spot cargo sales.

As to Pacific foreign shipments which, in addition to Central and South America, consist principally of shipments to Japan, China, Australia and New Zealand: A considerable portion of the business we had with Australia and New Zealand until four or five years ago is now being

Manuscript received at the office of the Institute Oct. 13, 1936.

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supplied from the East Indies. So far development of production in Russian Sakhalin has had little effect on our business with the Orient. Substantial reserves have been developed in Bahrein Island, and while it is too early to forecast what effect this supply will have on our shipments to Japan, substantial quantities of this crude are now being shipped into that country. Needless to say, if there is a considerable decline in the state's production, resulting in a materially higher price schedule for our crude, there will be a substantial reduction in our Pacific foreign business.

The same situation holds true in regard to our East Coast business. With the exception of shipment of some 15,000,000 bbl. of fuel oil during 1933 and 1934, which was in effect a reduction of the excessive stocks existing in California, fuel-oil movements to the east coast have been limited, shipments being almost entirely gasoline. If the production in Texas, Oklahoma and Louisiana holds up, as it gives promise to do, and the same relationship is maintained between the price schedules for Mid-Continent and California crudes, we cannot economically ship to the Atlantic seaboard. As an illustration, our present posted schedule is based on 27° gravity Signal Hill crude at \$1.10 a barrel, which by straight-run operations will yield around 27 per cent of gasoline, whereas 36° gravity Oklahoma-Kansas crude, which has a straight-run gasoline yield of around 36 per cent, is posted at this same price, and 36° gravity crude in West Central Texas, with about the same gasoline content, is posted at only \$1.00 a barrel. East Texas crude will yield about 36 per cent gasoline from straight-run operations, the present price schedule for which is \$1.15 a barrel. California is at a further disadvantage by reason of the difference in transportation costs to the Atlantic seaboard. Pipe-line transportation from Oklahoma to the Gulf is quoted at 32½¢ and from East Texas to the Gulf at 12½¢ a barrel, while steamer rates are now running about 22¢ a barrel from the Gulf to the Atlantic seaboard. This makes a total transportation cost of 54½¢ per barrel for Oklahoma gasoline and 34½¢ a barrel for East Texas gasoline moved to the east coast by water. As opposed to this, prevailing steamship rates alone from California to the Atlantic seaboard are about 60¢ a barrel, and not long ago ran as high as 84¢. Obviously, unless some adjustment is made of the disparity in the posted crude prices, any present or continuing surplus gasoline in California shipped to the Atlantic seaboard will have to be sold at a price that will not, after taking into consideration the realization from the other products, return the posted price for crude.

PRODUCTION AND CONSUMPTION

With the foregoing in mind, the question then arises why has California been continuing such large shipments out of the Pacific Coast territory during the last five years or so? Recalling the efforts put forth and the

sacrifices made to reduce the production of crude oil to profitable market demands, it would be well to consider what disposition has been made of the production during that period.

Before doing so, it is interesting to consider the increase in our Pacific Coast demand during the past 15 years and the growth of our offshore business following the development of the Los Angeles Basin fields. Also, the effect on our Atlantic foreign and intercoastal shipments of the flush production from the East Texas field starting in 1931. Our gasoline consumption and shipments during the 15½ years starting with Jan. 1, 1921, have been as set forth in Table 1.

TABLE 1.—*Gasoline Consumption and Shipments, California*
Barrels Daily

Year	Pacific Coast	Pacific Foreign	Atlantic Foreign	Inter-coastal	Total
1921.....	31,000	1,000			32,000
1922.....	39,000	1,000	1,000		41,000
1923.....	62,000	4,000	5,000	7,000	78,000
1924.....	56,000	3,000	12,000	8,000	79,000
1925.....	75,000	6,000	10,000	27,000	118,000
1926.....	84,000	11,000	15,000	23,000	133,000
1927.....	103,000	13,000	17,000	32,000	165,000
1928.....	109,000	19,000	23,000	46,000	197,000
1929.....	119,000	23,000	32,000	64,000	238,000
1930.....	126,000	23,000	34,000	56,000	239,000
1931.....	133,000	18,000	8,000	38,000	197,000
1932.....	125,000	21,000	10,000	23,000	179,000
1933.....	123,000	16,000	5,000	31,000	175,000
1934.....	130,000	15,000	4,000	24,000	173,000
1935.....	142,000	15,000	9,000	19,000	185,000
First half 1936.....	150,000	17,000	9,000	20,000	196,000

Taking only the last 5½ years, our crude oil consumption as compared with the quantity produced has been as shown in Table 2.

TABLE 2.—*Consumption and Production of Crude Oil, California*
Barrels Daily

Year	Consumption	Production
1931.....	520,000	516,000
1932.....	494,000	487,000
1933.....	484,000	474,000
1934.....	476,000	481,000
1935.....	566,000	569,000
First half 1936.....	600,000	594,000

It will therefore be seen that our consumption followed the same trend as production. In other words, primarily as a result of the curtailment efforts in 1932, the production averaged 29,000 bbl. a day less than the year previous and the consumption declined 26,000 bbl. a day. Likewise, the tremendous increase in production following the collapse of curtailment in the summer of last year resulted in the production for 1935 averaging 88,000 bbl. a day more than it did in 1934 and the consumption increased 90,000 bbl. a day, although, because of the impossibility of immediately developing markets to dispose of the surplus, it was reflected in additions to gasoline and fuel-oil inventories last year.

It is reasonable to assume that, in the main, our Pacific foreign shipments to date have been a part of our economic demand, since we have so far been the logical source of supply, but that our European and Atlantic seaboard shipments have principally been the result of surplus production. Let us consider, therefore, what our requirements would have been during the last 5½ years if no Atlantic foreign and intercoastal gasoline and crude shipments had been made, on the theory that these markets were retained solely to dispose of surplus supply. It is recognized that this is a controversial point, but the fact remains that as long as Mid-Continent and certain foreign crudes have a price advantage over California, we cannot, as stated before, after absorbing the higher transportation costs, realize a price for shipments to the Atlantic seaboard and to European markets that will return our posted price for crude.

TABLE 3.—*Requirements and Production of Crude Oil, California*
Barrels Daily

Year	Production	Not Including Shipments of Gasoline or Crude to Atlantic Seaboard and Europe		With Gasoline Yields Same as in Rest of U. S. and without Gasoline or Crude Shipments to Atlantic Seaboard and Europe	
		Requirements	Surplus	Requirements	Surplus
1931.....	516,000	417,000	99,000	319,000	197,000
1932.....	487,000	409,000	78,000	307,000	180,000
1933.....	474,000	405,000	69,000	307,000	167,000
1934.....	481,000	416,000	65,000	311,000	170,000
1935.....	569,000	479,000	90,000	356,000	213,000
First half 1936.....	594,000	499,000	95,000	390,000	204,000

Eliminating, therefore, the crude shipments into these markets, which are of little consequence and mainly to Europe, and the crude required to supply the gasoline shipments thereto, which, by the way, has been calculated on the basis of the gasoline yields during each of the respective years, our crude requirements, as compared with our actual production, would have been reduced to the figures given in Table 3.

During this period, because of the surplus crude constantly pressing on the market, cracking operations in California have been at a substantially lower rate than the rest of the United States, with the result that gasoline yields from total crude runs to refineries in California have been averaging around 33 per cent whereas east of California the yields have been running around 46 per cent.

If the gasoline yields from crude runs in California had been the same during that period as they were for the rest of the United States and we had made no gasoline or crude shipments to Europe and Atlantic seaboard markets, our crude requirements, as compared with the actual production, would have been as shown in Table 3.

Obviously, if the latter had been true, sales of both light and heavy fuel oils would have had to be substantially restricted because of the conversion of a larger part of the crude oil into gasoline. In this connection, however, because of the necessity of currently disposing of the crude oil being produced and because of the small quantity of gasoline extracted therefrom, it was necessary to develop markets for proportionately larger volumes of gas and fuel oils. Consequently, substantial quantities of these products were sold during the period at extremely low prices.

It is obvious therefore that a large part of our so-called demand during the last 5½ years actually represents shipments into markets maintained solely to take care of surplus supply.

TREND TOWARDS CRACKING AND DEMAND FOR FUEL OIL

Another factor that will have a definite bearing on future crude requirements is the trend towards increased cracking. The development in automotive engines in the last three years makes necessary large quantities of cracked gasoline to produce a motor fuel usable in the newer cars. If this increased cracked gasoline requirement is to be supplied by cracking residuum, even smaller quantities of refining crude oil will be required.

While California crude oil cannot, generally speaking, be cracked to the point of producing the same percentage of gasoline as, for example, the Mid-Continent crudes, it is safe to say that if market demand and price structure were such as to justify the cost, from 50 to 60 per cent gasoline could be produced from California refining crude with the type of cracking equipment that can be constructed today, and still leave a salable fuel oil.

If, however, a larger part of our crude production is to be converted into gasoline in the future, an equivalent quantity of existing fuel oil business will have to look to other sources of supply if our demand for products is kept in balance. In this event, the increased usage of fuel oil for cracking will materially strengthen the price therefor over what it

has been during the last five or six years. From the standpoint of the petroleum industry in California, however, this is an encouraging outlook in that it will ultimately result in a higher realization to the producer, since it must be recognized that the value of a barrel of crude oil is really the over-all realization from its sale in the form of products.

In passing, it might be of interest to point out that during the past five years or so both the Atlantic and Pacific fleets of the United States Navy have been stationed in Pacific waters. During this time the Navy has required annually about 7,500,000 bbl. of fuel oil. If the procedure were reversed, and the major portion of the fleet were transferred to Atlantic waters, our demand for fuel oil would be reduced accordingly. With the exception of steamship bunkers, the principal users of fuel oil on the Pacific Coast are the railroads. The figures for 1935 are not yet available, but railroad consumption during the preceding four years was as follows: 1931, 23,915,000 bbl.; 1932, 17,753,000; 1933, 16,887,000; 1934, 19,704,000.

With the trend toward Diesel equipment, it is apparent that, not only because of the increased speed but because of the materially lower fuel and operating costs, this type of equipment will come into more general use. While the petroleum industry will be called upon to supply the Diesel fuel, the quantity required will be substantially less than the fuel oil consumed by the locomotives thereby displaced.

FUTURE DEMAND OR CRUDE REQUIREMENTS

The question, then, is: What will be our future demand, or possibly better yet, what will be our crude requirements? The American Petroleum Institute recently published an exceedingly interesting survey captioned "A Survey of the Present Position of the Petroleum Industry and Its Outlook toward the Future." That survey, which covers the 25-year period, 1935-1960, was prepared in cooperation with the American Association of Petroleum Geologists and the industry's experts in production, demand, transportation, refining, marketing, taxation and labor, and goes into the subject in exhaustive and elaborate detail. It recognizes the probable increases in consumption resulting from increased population, motor-vehicle registration, the expansion of aviation, the greater use of buses and trucks for passenger and freight transportation, the extension of the use of Diesel engines, probable improvement in the efficiency of automotive and aviation equipment and the improvement in refining technique towards increasing the available supply of motor fuel by the extension of cracking operations, hydrogenation, polymerization and the substitution of alternative fuels, etc.

From the standpoint of demand, the most outstanding point is that while motor-fuel requirements are estimated to increase from 432,000,000

bbl. in 1935 to 657,000,000 bbl. in 1960, as a result of the forecasted steady increase in gasoline yields from crude runs, crude requirements only increase from 919,000,000 bbl. in 1935 to 1,071,000,000 bbl. in 1960, as shown in Table 4.

TABLE 4.—*Estimated Increases in United States*

Year	Motor Fuel Requirements, Bbl.	Gasoline Yield from Crude, Per Cent	Crude-oil Requirements, Bbl.
1935	432,000,000	43.8	919,500,000
1940	563,880,000	48.0	1,099,000,000
1945	599,900,000	51.0	1,104,080,000
1950	636,570,000	54.0	1,109,800,000
1955	647,160,000	56.0	1,087,930,000
1960	657,490,000	58.0	1,071,020,000

It is appreciated that the outlook for the expansion and development of the Pacific Coast is not comparable with that of the United States as a whole; that we do not have the closely populated areas of the East; that our farming lands are not as fully developed as those in the Middle West; that we do not have the same condition of nonusers of motor fuel as exists in the metropolitan areas of the East and in certain sections of the South. Consequently, we should be justified in looking forward to a greater increase in consumption of motor fuel on the Pacific Coast during the next 25 years than has been forecast for the United States. Assuming, however, that our increase is only at the same rate as forecast for the United States, that we retain only our existing Pacific foreign business of both gasoline and crude oil and that our gasoline yields were increased to the same percentage as set forth in the American Petroleum Institute report under discussion, our future outlook would be as shown in Table 5.

TABLE 5.—*Estimated Increases in California*

Year	Gasoline Demand, Bbl. Daily			Crude Requirements, Bbl. Daily		
	Pacific Coast	Pacific Foreign Shipments	Total	To Supply Gasoline Demand	Pacific Foreign Shipments	Total
1940	184,000	15,000	199,000	348,000	39,000	387,000
1945	196,000	15,000	211,000	346,000	39,000	385,000
1950	207,000	15,000	222,000	345,000	39,000	384,000
1955	211,000	15,000	226,000	338,000	39,000	377,000
1960	214,000	15,000	229,000	332,000	39,000	371,000

In connection with these indicated crude requirements, it will be recalled that our crude-oil production is now averaging around 580,000 bbl. daily.

Numerous estimates have been made up by qualified petroleum engineers, the California Oil Umpire's Office and the American Petroleum Institute, which set the future developed crude-oil reserves of California between $2\frac{3}{4}$ billion and $3\frac{1}{2}$ billion barrels. It is recognized that such estimates have to be predicated entirely on known existing fields, sands and structures and, consequently, have to be constantly revised. Using 3 billion barrels, however, as a basis, our reserves are sufficient to supply the foregoing indicated requirements for about 20 years. If the Pacific foreign shipments were also eliminated—which, of course, could not be done until the current crude-oil production was reduced to Pacific Coast requirements—this reserve would be sufficient to supply the Pacific Coast requirements for about 25 years. At the same time, as a result of increasing our gasoline yields from the present 33 per cent to 48 per cent in 1940 and then to 58 per cent by 1960, we should, as before discussed, be required to substantially reduce our fuel-oil business. On the other hand, if we continue our present rate of consumption, our reserves, on the basis of 3 billion barrels, would be depleted in about 15 years; provided, of course, the oil could be produced in so short a period.

FUTURE SUPPLY AND DEMAND IN CALIFORNIA

It would, therefore, seem that unless some undiscovered flush fields or deeper sands of large importance are presently developed in California, our question is answered—that the future demand for California petroleum products will be as in the past, our available supply, but that in the future it will not include the disposition of a surplus over and above our economic markets.

Therefore, if present estimates of California reserves closely approximate the ultimate recovery, we will, within a very few years, see the entire elimination of shipments to Europe and the Atlantic seaboard and will also see a material reduction, if not an entire elimination, of shipments to Pacific foreign markets. This should not be viewed, however, with alarm but as an optimistic outlook for the California producer and, in turn, the people of the state by reason of the greater revenue that will be possible from the utilization of California's most important natural resource.

As to supplying our own requirements, there should be no fear regarding a shortage, for, as before mentioned, the present-day refinery methods make it possible, if necessary, to convert a considerably larger portion of our crude supply into motor fuel, which is the most important product. Furthermore, it is generally accepted that future improvements in refinery engineering will, if required, provide an even larger recovery than is now possible.

Possible shortage of petroleum in California, however, is not a new story. Quoting from a booklet published in 1928 by Chamber of Mines and Oil, the forerunner of the present California Oil and Gas Association:

The year 1900 was of further importance because it headed a 7-year period of over-production. . . . By 1906, when the state's output had climbed to over 32 million barrels, oil was generally adopted as a locomotive fuel. This not only brought relief but soon caused consumption to overtake and exceed production. The shortage however, was ended in 1909, when the state production increased to 58 million barrels. . . . The Coyote and Whittier fields became heavy producers in 1912, and in 1914 the total state production reached the record figure of nearly 104 million barrels. Immediately thereafter, production showed a sharp decline and it was not until 6 years later that the record of 1914 was again equalled. In the meantime reserve stocks of crude oil were drawn upon steadily, so that when the United States entered the world war in 1917 the increased demand for petroleum threatened to create a shortage in California. . . . Some relief was effected by the discovery and development of the Montebello field in 1917, and by heavy production in the Richfield and Elk Hills fields in 1919. Production continued to lag, however, until 1920, when Montebello, Elk Hills, and Richfield added 21 million barrels to the state's output. By this time reserve stocks of crude had been reduced to 22 million barrels.

We were so alarmed because of the 1920 shortage of crude oil that trainloads of gasoline were shipped into this territory from the Mid-Continent and cargoes of crude naphtha were imported from Mexico. This was all changed by discovery of new fields, such as Santa Fe Springs in 1923, which produced in that year alone 80 million barrels of crude oil, as compared with a total of 104 million barrels for the entire state in 1920.*

DISCUSSION

(*W. H. Geis presiding*)

H. H. POWER,† Austin, Tex.—I should like to hear a little bit more about the Lost Hills discovery.

J. JENSEN, ‡ Los Angeles, Calif.—The second zone is producing about 100 bbl. and the third one is producing about 400 to 500 bbl. In the fourth, in one place, we found water. How wide it will be and how far it will extend, no one knows.

V. H. WILHELM,§ Los Angeles, Calif.—We keep books on the oil industry in California, adding our estimate of the new reserves and subtracting the yearly withdrawals. Estimates of reserves are our opinion of all producible oil at present prices. Naturally our estimates of reserves increase when the price of oil is raised. Mr. Minshall's paper (p. 261, this volume) is a very careful estimate of the situation, and reflects the generally accepted idea that California reserves are not sufficient in view of present withdrawals.

J. JENSEN.—When are supply and demand going to cross each other?

V. H. WILHELM.—Supply and demand curves are approaching each other, but I consider that there will be adjustments in the industry so that it is probable that there never will be a shortage of oil in California. These adjustments may be increased

* A chart illustrating the close relationship between production and indicated demand since 1914, the fluctuation in total stocks and in the price structures for crude oil, gasoline and fuel oil, and the effect that shortage and surplus of supply have had on price structure may be obtained from the author, Mr. Hand.—Ed.

† Department of Petroleum Production, University of Texas.

‡ Chief Petroleum Engineer, Associated Oil Co.

§ Chief Petroleum Engineer, The Texas Company.

reserves, due to increased prices of oil; loss of unnatural markets, such as Atlantic Coast and Atlantic foreign; and improvements in automobile design, necessitating less fuel.

J. M. LOVEJOY,* New York, N. Y.—I want to commend Mr. Hand for the excellent presentation of his paper. He makes conclusions appear very simple, which cannot always be said of economic discussions.

Incidentally, I recently reviewed a paper prepared for the World Power Conference, which contained a number of tables and charts relative to the number of wildcats drilled over certain periods, and the amount of reserves discovered during those periods. It is interesting to note that so far throughout the history of our industry there has been a direct relation of discoveries and the number of wildcats drilled. It appears from the charts that discoveries depend on the quantity rather than the quality of wells drilled. Since 1930, owing to the depression and low prices for crude, there have not been as many wildcats drilled as in the preceding five-year period, and, as a result, we have not discovered since 1930 quite as much oil as has been taken out. If we fall behind in our rate of discovery, it will of course be necessary to establish higher prices in order to stimulate exploration.

In California it is quite possible that we may be entering a new era of discovery. There have been no major discoveries in California since 1928. Admittedly, the area of possible productive territory in California is limited, but it seems to me that even that limited area offers plenty of room for new major fields. I agree with Mr. Hand that California need have no worry about an oil shortage, because, as he so clearly points out, California can refrain from shipment to the East Coast and to foreign countries before there will be any shortage for the local demand on the Pacific Coast.

H. N. MARSH,† Los Angeles, Calif.—It is unnecessary to comment on the excellence of Mr. Hand's analysis, but it might be in order to question the basic data, which presumably he has accepted from geologists. There is a great deal of practical evidence to indicate that the way in which a field is produced has tremendous effect on the amount of oil that ultimately will be recovered from it. These estimates of reserves are based on production practices as they were in the past, as they are now, or as they may be in the future.

A. H. Bell,‡ Los Angeles, Calif.—No matter how inefficient we may have been in developing or exploiting, from a practical standpoint, all the fields that have been producing from the start in California are still producing and the probability is that all the fields will be in the picture at the time when the shortage arises and we have higher prices. The higher price will furnish the income to make up for the inefficiency in previous practice, and the ingenuity of the engineers under the higher price will cause us to recover just as much oil in the end as if we had operated under the most efficient methods at the start. I do not think that any field is going to be abandoned until all of the oil is recovered. For instance, take Pennsylvania. Pennsylvania was out of the picture until 20 years ago, but now it has proration. It is conceivable that we may see the day in California when 600-ft. shafts will be sunk and some of these heavy oil sands that are not so deep will be mined.

In my opinion Marsh's question can be answered to the effect that if we properly estimate the amount of oil in the reservoir we will ultimately get it all out.

H. N. MARSH.—I think Mr. Bell is academically correct, but I wonder if these estimates are not based on oil recovery by present practices rather than by mining.

* President Seaboard Oil Co. of Delaware.

† Production Engineer, General Petroleum Corporation of California.

‡ General Superintendent, Continental Oil Co.

F. A. MORGAN,* Los Angeles, Calif.—I should like to ask Mr. Hand's expert advice on a question that has interested me very much in the last few months. I have spent some time in a small town where there is no natural gas supply. A very good friend of mine has a fine old home. It has been the practice to make improvements in small towns such as this, of which there are thousands all over the United States, very slowly. For heating it has been the practice for years to struggle along with oakwood that the farmers bring in or with blocks that they slash at the mill. This provides all the fuel that is available. Apparently the real advantage of using oil to heat their homes has not been brought to the attention of these people.

I convinced my friend of the logic or good business of trying a system of heating with oil in his home. He had never given it a serious thought. He did not have a basement, so he built a tank and piped in the oil and with five or six stoves he now burns between 400 and 500 gal. of oil a year. This is the first installation of that kind in that town. Now his neighbor is going to try it. This man burns more of this oil in his home for heating than he burns gasoline measured in gallons in his car during the year.

I should like Mr. Hand to suggest what it might mean if 10,000 or 10,000,000 such homes in the United States should use oil, particularly in districts where they would not be competing against the natural or artificial gas supply.

A. H. HAND.—Furnace heating has been to the fore on the east coast in the last two years. It is reported that during that period there have been over one million oil heaters installed in the New York metropolitan area alone. These burners, they tell me, consume on the average about 25 bbl. per year, which would require 25,000,000 bbl. of furnace oil annually just for that territory. Oil heating is much cleaner and more convenient to handle than coal, and the price of oil so far has been advantageous to the consumer. There is a limited quantity of this product that can be recovered from a barrel of crude oil, however, and if the demand increases the price will have to advance to an economic level. As the product becomes more in demand, the price advantage that exists today will gradually disappear. It is the law of supply and demand again.

Specifically answering the question, there is no doubt that oil for domestic heating is going to have a tremendous increase in this country. Whether or not that is going to occur in California, I do not know. Not, I think, in areas adjacent to gas supplies. There has been some movement towards the shipment of gas in containers, but the cost of transporting the containers has so far made it uneconomical. For an illustration, let us take an area like Lancaster, where there is no gas available. How much of the population there could afford to install oil burners? Certainly not enough to justify the oil companies in going to the cost of additional tankage. That oil is off-color. It means separate tanks, pumps and trucks and costly distribution, so that a satisfactory price for the product cannot be made unless there is a large demand.

The same situation I have described for furnace oil is true for the heavier oils. The fuel-oil requirements of the east coast are handled by the integrated companies almost exclusively and practically the same situation holds true here. A large volume of the fuel-oil business is for ships' bunkers. To handle that there must be terminals, pipe lines, and barges, which means that the smaller companies in the gasoline and lubrication-oil business cannot afford the cost of equipment. So it leaves the business almost entirely to the larger companies. And what price do they get for their fuel oil? Is the current 95¢ posted for bunker fuel oil a comparative price based on a \$1.10 schedule for crude oil? You can analyze it and come to your own conclusions.

* Geologist, Rio Grande Oil Co.

The price of fuel oil on the east coast today is stronger than it has been for a long time past, and has reached the point where a considerable number of hotels, apartments and office buildings that were using fuel oil because of cost are going back to coal. I believe it is the general opinion in the East that \$1.50 per barrel is about the saturation point for fuel oil on the basis of the existing price for coal. When the price drops below that, they can more profitably use fuel oil.

My own idea is that the petroleum industry should not try to supply every requirement that comes along but should put a price on its products that will justify a fair return to the producer and let unprofitable business go to other sources of supply. When we do that, we'll get a higher price for our fuel oil, our gas oil and our furnace oil, and will in return be able to pay a higher price for refining crude without having to get any more for our gasoline.

A. H. BELL.—One point has not been brought out here, seven or eight years ago a tremendous amount of fuel oil was displaced by the surplus gas that was on the market. The utilities, especially at San Francisco, took on the Kettleman Hills gas and displaced the fuel oil.

We know that our gas supply in California is primarily from oil fields. We know further that the gas of any importance ceases about the time the flush production is over, and I would guess that 75 per cent of our oil reserves will be produced without any important by-production of gas. We know from other papers at this meeting that North Belridge and Kettleman produce 55 per cent of the gas supply of California. We have all our eggs in two baskets, and we have evidence that our major source is slipping, and it appears to me that we are approaching a shortage of gas even faster than we are approaching a shortage of petroleum. When that shortage appears, all the industrial load will be converted from gas to fuel oil, and we will have a pickup in fuel oil that will probably be of very substantial proportions.

A. H. HAND.—I deliberately ducked the gas problem. There is a possibility of new gas discoveries in California. However, if there is not, I think we are going to have to produce water gas, go farther to hydroelectric power or find some other substitute, because if the crude situation is as described there will not be sufficient fuel oil available at a price that will justify its conversion into artificial gas. It is a difficult subject to consider and I do not think it has any bearing on our supply and demand of petroleum.

J. JENSEN.—Mr. Bell, on Oct. 9 the first Boulder Dam power will be here in Los Angeles, and that will come in continuously in increasing amounts. We are going to have an enormous amount of electricity in California, and I think that the electricity industry will suffer as we have because of oversupply.

MEMBER.—I should like to ask about the importation of foreign oil in California. Is it not possible that some of the South American countries can furnish us oil at a certain price? As a matter of fact, if the price of oil gets too high in California, is there not a very strong possibility that there will be imports of foreign oil?

A. H. HAND.—I think the papers brought out that we have ample supplies for our own requirements, and before we would import much into California we would cut out all our exports. We now have an import tax of 21¢ per barrel, and there has been a great deal of agitation to double the tax to 42¢. I think that with the present attitude of the Government on tariffs it will be a long while before oil can be imported into California at a price that will enable us to refine it and reship the products.

Future Supply of Oil in California

BY F. E. MINSHALL*

(Los Angeles Meeting, October, 1936)

FOR more than 30 years California has been one of the three leading oil-producing states. Present daily production of crude oil under curtailment, approximately 580,000 bbl., comes from three general areas: Los Angeles Basin, San Joaquin Valley, and the coastal region of Ventura and Santa Barbara Counties. This state produces approximately two-thirds of its oil from eight large fields, and obtains a daily average production of 48 bbl. of oil per producing well, whereas the average for the United States is but 8.15 barrels.

During the closing stages of the first half of 1936, discovery of the Section Ten oil field was made, and credit goes solely to geophysical work. It is the first direct important discovery of oil in California that may be credited to geophysics.

This discovery may furnish the cue to the means of discovering several fields in California, particularly in the San Joaquin Valley. It is a question, however, whether returns from geophysical work will play as important a part in the future supply of oil in California as have our former types of prospecting.

EXPLORATION

Methods of prospecting have progressed in the oil industry through invention or improvement in scientific means of locating and defining structure and because of market improvements in drilling equipment. Present methods of prospecting include:

1. A detailed study of geology in an attempt to locate structural and stratigraphic conditions that would be favorable to the accumulation of oil.

2. Geophysical methods involving the use of the seismograph, torsion balance, magnetometer and electrical methods. (There is still much to be learned in California in the application of geophysical methods.)

3. Use of micropaleontology as an aid in correlation.

The principal improvements in drilling equipment are:

1. The Schlumberger dipmeter, which determines the direction of formation dip in an uncased hole.

Manuscript received at the office of the Institute Oct. 13, 1936.

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2. The geoanalyzer—an automatic electric logging device.
3. Stratagraph—an electrical logging device used in detecting shale bodies through the casing in boreholes.
4. Halliburton recorder, which records changes of formation pressures during formation or shutoff tests.
5. Controlled directional drilling.
6. Unitized rotary-drilling machinery.
7. Wire-line core bits.

DISCOVERIES DURING FIRST HALF OF 1936

Developments of special significance in California during the first half of 1936 were as follows:

1. The discovery of the Padre Canyon oil field, Ventura County, in March 1936 by Continental Oil Co. upon completion of its well Hobson No. 1, at a depth of 5501 ft., producing 570 bbl. per day of 30.0°+ gravity.
2. Completion of the first large well in the Santa Maria Valley field by Union Oil Co. This completion had an initial daily flow of 2380 bbl., 16.4° gravity, at a depth of 2576 feet.
3. The discovery by Shell Oil Co. of the Section Ten field, Kern County, on June 2, 1936, with its Stephens No. 1 well producing 800 to 1000 bbl. daily, 61° gravity, 15 million cubic feet of gas, at a depth of 7888 feet.

PRODUCTION

For the purpose of comparison, California's total production for the year 1929 to the first half of 1936, inclusive, is listed in Table 1 in yearly totals and as daily averages.

TABLE 1.—*California Total Production*

Year	Yearly Totals, Bbl.	Daily Averages, Bbl.
1929.....	292,036,911	800,101
1930.....	228,099,899	624,931
1931.....	188,829,032	517,340
1932.....	178,127,794	486,688
1933.....	173,083,319	474,201
1934.....	175,678,362	481,310
1935.....	207,899,520	569,587
1936, first half.....	108,160,769	594,289

Production of oil in California has been curtailed since 1929. The amount of curtailment below actual potential during the period has been conjectural. It is certain that the differences between actual potentials and the curtailed rate was much less than indicated by the Umpire's

figures. In other words, potentials generally and in detail were higher than could be maintained. During 1936 some fields, notoriously producing wide open, could not make their allowables, let alone their potentials.

Overproduction problems in California appear to be solved unless many new pools are discovered in rapid succession.

The eight leading fields in 1935 and their total production were:

	BARRELS
Kettleman Hills, North Dome.....	27,569,892
Midway-Sunset.....	20,243,760
Mountain View.....	9,239,871
Ventura Avenue.....	10,986,096
Dominguez.....	7,913,492
Huntington Beach.....	15,185,343
Long Beach.....	26,487,238
Santa Fe Springs.....	16,163,733
Total.....	133,789,425
All other fields.....	74,110,095
Total California.....	207,899,520

PAST PRODUCTION AND RESERVES

Oil fields of California produced 4,566,114,288 bbl. of oil to July 1, 1936—an average production of 45,600 bbl. per developed acre. At the same date, there were 149,459 acres of proved oil land in California, approximately two-thirds of which has been developed. Table 2 shows

TABLE 2.—*Relations between Number of Wells and Proved Acreage in Principal Districts*

Field	Number Producing Wells	Proved Acreage	Developed Acreage	Developed Acres per Well
Coastal.....	1,676	28,470	18,600	11.1
Los Angeles Basin.....	5,631	18,870	16,454	2.9
San Joaquin Valley.....	9,530	102,119	65,481	6.9
Total.....	16,837	149,459	100,535	5.9

the relation between number of producible wells, proved acreage, developed acreage, and acres per well in the three principal districts. Interesting facts gathered from the table are:

Los Angeles Basin fields are for comparison practically fully developed with an average of 2.9 developed acres per well.

San Joaquin Valley contains a large majority of undeveloped proved acreage.

Facts on future supply of oil in California are gathered from all available sources and this mass of information is classified, correlated and

used as a basis in making estimates of reserves. Such data on oil reserves is valuable if used correctly in making general forecasts for supply and

TABLE 3.—*Past Production and Reserves of Petroleum in California*

Field	Production to July 1, 1936		Estimated Future Production	Estimated Ultimate Production	
	Total	Per Proved Acre		Total	Per Proved Acre
Coastal (includes miscellaneous).....	432,783,915	15,200	270,363,986	703,147,901	25,000
Los Angeles Basin....	2,182,955,349	116,000	569,811,923	2,752,767,272	145,000
San Joaquin Valley...	1,950,375,024	19,100	1,875,625,077	3,826,000,101	37,500
Total.....	4,566,114,288	30,600	2,715,800,986	7,281,915,274	49,000

demand and in comparing past production of various fields with future supply.

On the basis of an estimated ultimate production of 7,281,000,-000 bbl. for the state, future supply of oil in California approximates

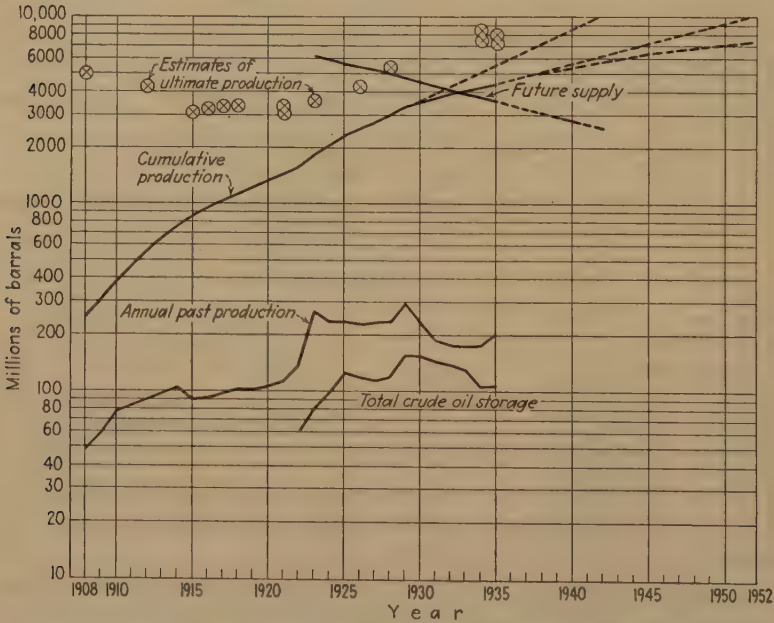


FIG. 1.—COMPARISON OF ESTIMATES OF CALIFORNIA OIL RESERVES AND PRODUCTION. x in circle indicates estimates of ultimate production.

2,716,000,000 bbl. Table 3 shows the relation between past production and reserves in the three principal districts.

No estimate of reserves for the three discoveries made during the first half of 1936 are included in Table 3, because very little is known as to the extent of these new fields.

Most of California's production and reserves are in the Pliocene and Miocene rocks of Tertiary age. Rocks older than Miocene supply very little of the production.

TABLE 4.—*Comparison of Estimates of California Oil Reserves, Annual Production and Cumulative Production*

Date of Estimate	Estimate by	Estimates Ultimate Production, Proved Oil Land, Bbl.	Annual Production, Bbl.	Cumulative Production, Bbl.
1908	U. S. G. S., Day, Arnold	5,000,000,000	48,307,000	250,495,000
1909			58,192,000	308,687,000
1910			77,698,000	386,385,000
1911			83,744,000	470,129,000
1912	M. L. Requa, A. F. L. Bell	4,225,000,000	90,074,000	560,203,000
1913			97,867,000	658,070,000
1914			103,624,000	761,694,000
1915			89,567,000	851,261,000
1916	Ralph Arnold	3,041,274,000		
	U. S. G. S., U. S. B. M. Sen. Doc. 310	3,223,365,000	91,822,000	943,083,000
1917	Bur. Mines, C. H. Beal	3,300,000,000	97,268,000	1,040,351,000
1918	David White	3,364,000,000	101,638,000	1,141,989,000
1919			101,222,000	1,243,211,000
1920			105,721,000	1,348,932,000
7-1-21			114,850,000	1,463,782,000
	Calif. Com. A. A. P. G. U. S. G. S.	{3,095,000,000 {3,314,000,000		
1922			139,627,000	1,603,409,000
7-1-23	R. E. Collom and R. M. Barnes	3,544,000,000	263,729,000	1,867,138,000
1924			230,063,000	2,097,201,000
1925			230,147,000	2,327,348,000
1926			224,117,000	2,551,465,000
1927	A. H. Heller	4,307,064,000	230,751,000	2,782,216,000
1928			5,414,000,000 ^a	3,014,199,000
1929			292,037,000	3,306,236,000
1930			228,100,000	3,534,336,000
1931			188,829,000	3,723,165,000
1932			178,128,000	3,901,293,000
1933			173,083,000	4,074,376,000
7-1-34	L. P. Stockman	{8,448,700,000	175,678,000	4,250,054,000
	R. E. Collom	{7,466,400,000		
1935	A. A. P. G. Com.	7,958,000,000	207,900,000	4,457,954,000
	V. H. Wilhelm	7,182,000,000		
7-1-36			216,000,000 ^b	4,673,000,000 ^b

^a Kettleman Hills, Santa Fe Springs, Buckbee and Nordstrom zones, Elwood (Vaquerous zone).

^b Estimated.

Table 4 and Fig. 1 shows comparison of estimates of California oil reserves, annual past production and cumulative production. Fig. 1 shows that the various estimates of ultimate production occur at irregular intervals. Since 1923 these estimates have been increasing at approximately the same ratio as cumulative production. Whether the sameness of these increasing ratios is accidental or has been used as a safety factor is controversial. However, withdrawals from proven reserves have been greater than the amount added by the discovery of new fields during the last seven years.

Using 8,000,000,000 bbl. for California's estimated ultimate production as a basis, a decline of estimated future reserves for the past 14 years has been calculated and plotted on Fig. 1. The crossing of the two curves, cumulative production and estimated future production, indicates that total past production and estimated future were approximately equal during the period 1932-1933. Extension of the average trend of these curves has been made to illustrate what the picture ahead looks like without making any allowance for new supply.

CONCLUSION

To balance California supply and demand, it is important that reserves be increased approximately 2,000,000,000 bbl., to approach an ultimate reserve of 10,000,000,000 bbl., within the next five-year period. Where are the additional reserves? The known oil provinces of California—Coastal area, San Joaquin Valley and Los Angeles Basin—where these future reserves are most likely to be found, probably will not be enlarged. Approximately all of California's future supply will come from some combination of the following:

1. Discovery of deeper sands in known proved fields.
2. Redrilling of wells in old fields.
3. Drilling to depths of 10,000 to 12,000 ft. deep tests in numerous plays, which have already been tested to depths of 5000 ft. or less.
4. Buried structures that may be found by geophysics.

Developments in Petroleum Marketing

BY SIDNEY A. SWENSRUD,* MEMBER A.I.M.E.

THIS paper reviews the subject of gasoline margins, discusses some of the more current marketing problems, and gives some consideration to the main urges to marketing expansion, or overexpansion, in the oil industry.

MARGINS

In an earlier paper¹, some comparisons were shown for the years 1929, 1930 and 1931, of the margin between the refinery cost of gasoline in Oklahoma, the market price in Oklahoma, and the average retail price in 50 representative cities of the United States. These figures indicated a small margin for the refiner in 1929 between his gasoline cost and the wholesale price, which, however, had turned into a loss by 1931. The margin between either refinery costs or wholesale prices and the retail price in the 50 cities showed a continuous decline during the three years.

We have now worked out these figures on a similar basis for a longer period—from 1928 through 1936. The figures for refinery gasoline cost are slightly different from those in the earlier study, owing to the use of

TABLE 1.—*Gasoline Costs and Prices at Refineries in Oklahoma*

Year	A	B	C	
	Cost, Cents per Gal.	Price, Cents per Gal.	Profit Margin (A - B), Cents per Gal.	
			Profit	Loss
1928	6.80	7.97	1.17	
1929	7.10	7.60	0.50	
1930	6.70	6.15		0.55
1931	4.60	3.62		0.98
1932	5.40	4.50		0.90
1933	4.20	3.80		0.40
1934	5.50	4.60		0.90
1935	5.10	5.35	0.25	
1936	5.50	5.86	0.36	

Manuscript received at the office of the Institute Feb. 5, 1937.

* Assistant to the President, Standard Oil Company (Ohio), Cleveland, Ohio.

¹ S. A. Swensrud: Factors Affecting the Demand for Gasoline and Crude Oil over the Next Few Years. *Trans. A.I.M.E.* (1933) **103**, 53.

more accurate data now available on crude-oil transportation and refinery costs².

The gasoline cost figures arrived at and the wholesale refinery prices in Oklahoma for the years in question are shown in Table 1. These figures show that from 1930 through 1934 the refiner paying for crude oil at the well price plus pipe-line tariff rates was unable to make gasoline at a cost as low as the prevailing refinery prices. In other words, a marketing company buying its gasoline in the wholesale market during those years had a better marketing margin than did the refiner-marketer.

The margin between the wholesale price of regular grade gasoline in

TABLE 2.—*Wholesale and Retail Prices^a of Gasoline*

Year	Average Retail Price of Regular Gasoline in 50 U. S. Cities, Cents per Gal.	Price of Gasoline at Oklahoma Refineries, Cents per Gal.	Margin of Retail Price over Wholesale Price in Oklahoma, Cents per Gal.
1928	17.90	7.97	9.93
1929	17.92	7.60	10.32
1930	16.17	6.15	10.02
1931	13.00	3.62	9.38
1932	13.30	4.50	8.80
1933	12.41	3.80	8.61
1934	13.64	4.60	9.04
1935	13.55	5.35	8.20
1936	14.00	5.86	8.24

^a Prices are exclusive of taxes.

² The method of arriving at refinery gasoline costs in Oklahoma was to add together the well price of crude oil, the rate for pipe-line gathering and delivery into the refinery and the cost of processing the crude into the typical refined products indicated in the Bureau of Mines reports for the Oklahoma-Kansas-Missouri district. From such total was then deducted the wholesale value of the products other than gasoline and the balance of expense remaining was assumed to be the cost of gasoline produced.

A summary of the detailed calculations are as follows (based on refining one 42-gal. barrel of crude):

Year	Price of 36° Crude at Well	Gathering Rate Plus 3¢ Marketing	Processing at Refinery	Total Costs	Value of Non-gasoline Products	Balance of Expense against Gasoline	Gal. Gasoline per Bbl. Crude	Cost per Gallon
1928	\$1.31	\$0.23	\$0.38	\$1.92	\$0.50	\$1.42	21.0	\$0.068
1929	1.36	0.23	0.38	1.97	0.50	1.47	20.7	0.071
1930	1.24	0.23	0.40	1.87	0.39	1.48	22.3	0.067
1931	0.65	0.23	0.40	1.28	0.28	1.00	21.9	0.046
1932	0.87	0.23	0.42	1.52	0.33	1.19	22.0	0.054
1933	0.62	0.20	0.42	1.24	0.33	0.91	21.7	0.042
1934	1.00	0.15	0.46	1.61	0.41	1.20	21.8	0.055
1935	1.00	0.13	0.45	1.58	0.47	1.11	21.8	0.051
1936	1.10	0.13	0.45	1.68	0.48	1.20	21.8	0.055

Oklahoma and the retail price of similar gasoline in 50 representative U. S. cities shows a steady downward trend through the whole 9-year period, except in 1934, when the trend was temporarily interrupted by the N.R.A. Code. The figures are shown in Table 2.

As seen in these figures, the reduction in the over-all margin from the 1928-1930 era to the present time has been about 2¢ a gallon. It would be wrong to conclude that all this reduction has come out of marketing. The margin shown in Table 2 is a transportation and marketing margin, and probably at least half the reduction has been in the item of transportation, either directly or in the form of crude oil, from the crude-oil sources to bulk stations. These reductions in transportation have resulted from the substitution of water, truck transport, or pipe-line shipments for rail shipments, gasoline exchanges among refiners, and to a slight extent reduction in rail rates. As for the balance of the reduction in margins, which has come out of the marketing end, the factors at work seem to be the same as those mentioned in the earlier paper, particularly the lower retail prices forced by the trackside and other cut-rate types of marketers. Also, as we shall point out later, there have been reductions in handling and delivery costs within the jobber function.

The story of declining margins, however, is not fully disclosed by analysis of regular grade gasoline alone. Declining percentage of premium fuel, reduction in the amount of the premium, declining relative consumption of oil and the gross margin thereon are contributing factors only slightly offset by profit margin on tires and other non-petroleum products.

MARKETING PROBLEMS

Coming to more immediate problems, there are four essential marketing questions before the oil industry:

Who shall do the retail marketing?

Who shall provide the capital facilities for marketing?

What shall the gasoline price structure be?

How much rationalization machinery in the way of codes, legislation, and the like shall be had?

Who Shall Do the Retail Marketing?

Many people seem to think that so far as retailing is concerned, the question of who shall do the marketing has been settled finally and completely by the "Iowa Plan." The writer was born and raised in Iowa, but so far as this question is concerned, he's from Missouri.

What is the "Iowa Plan"? Is it merely the leasing out of a large proportion of major company-owned stations? No, that had been going on for a long time before the Iowa Plan was heard of, purely as a matter

of economy and to obtain the best efforts of individuals preferring to work for themselves. The distinction, we believe, is that under the Iowa Plan the major company leases out *all* its service stations and hence ceases to be a retailer or to post retail prices.

One hears various reasons assigned for the adoption of the Iowa Plan, such as chain-store taxes, the Robinson-Patman Bill, social-security taxes, etc. All of these probably are contributing factors, but none of them, we believe, has been the main reason. In most states where the Iowa Plan has been put into effect there either were no chain-store taxes or none applicable to service stations. The Robinson-Patman Bill had not been heard of when the Iowa Plan was first put into operation, nor had the social-security laws been enacted.

In so far as these measures put a burden upon salary operations which is not borne by individual dealers, the latter form of operation, of course, is promoted at the expense of the former, and service stations, being small, separately operated units, can be shifted over to individual proprietors, in contrast to other activities, such as refining, which requires a large aggregation of workers in one place whose efforts must be closely coordinated and carefully directed.

The above-mentioned expense items, however, are not as important as the increase in service-station wages for many companies and the shortening of hours of salaried employees as compared with conditions three or four years ago. It was, of course, a vain hope on the part of service-station workers as a whole that, in the absence of any similar provisions as to individual dealers, high wage and low hourly schedules could be applied to company-operated stations without causing a fundamental change in methods of operation. The experience of N.R.A., however, probably demonstrated as clearly as anything that the preservation of the small, individual entrepreneur's independence and right to work as long as he pleases for as little as he chooses, is at least as sacred a part of the American economic and political system as the hopes and demands of wage earners.

It is noteworthy that the philosophies of these two groups come peculiarly into conflict in the retail end of the oil business, which is carried on largely in one-man units. The Oil Code sought to avoid this conflict by forbidding any effective change in status of operation; but even this could not prevail against the forces at issue, and widespread leasing of stations had commenced even before the N.R.A. expired.

The foregoing factors constitute no reason *per se* for leasing *all* company stations, however. That practice must be attributed to other reasons. One of these, we believe, is the desire to get increased gallonage into company stations through the more personal efforts and the greater price flexibility characteristic of individual dealer operations. Most large companies seem to have concluded that they can not permit salary

stations to grant discounts to selected customers such as truck operators, but must have only one price for each product. Equally strong, however, seems the conviction that not all customers desiring to buy at retail can be induced to pay the same price, and the dealer seems better adapted than the salaried operator to extend to certain classes of customers the necessary commercial discount.

The last, and perhaps most important reason for leasing *all* stations is the fact that thereby the company ceases to have any direct responsibility for retail prices and consequently for the dealer margin. So long as a company sells both to dealers and at retail it must establish both dealer and retail prices, and by definition the differential between them, which is the dealer's margin. By and large, however, the dealer wants a wider margin, and is often persuaded that if his supplier would only raise the retail price without increasing the dealer price no harm would be done and he would have his much desired extra margin. Naturally, few things would appeal to the major company supplier operating retail stations more than to have a higher retail price, but long experience has made it clear that too high a retail price brings its own penalty through the opportunity it gives for open price cutting on the part of trackage stations and the like, and for secret discounting on the part of all other types of marketers.

It is often difficult, however, to convince dealers of the reality and importance of these price-making forces, and since the question of margins tends to become a semipolitical one, some people think there is an advantage in allowing retail dealers to settle for themselves the question of what the retail prices are to be, the major companies terminating their interest in price with the sale and delivery of the gasoline to the dealer, thereby divesting themselves of the whole responsibility for retail prices and dealer margins.

If this last consideration is one of the main reasons for the complete leasing out of stations, it is perhaps pertinent to examine the question of whether the major supplying companies *can* thus easily shed the responsibility for dealer margins and can divorce themselves from all interest in and concern with retailing and retail prices. We do not believe they can. Certainly the assumption that the dealer under the competitive system can in some way fix the retail price to his own liking involves a new concept of price determination; namely, that the competitive forces heretofore operating to determine retail prices are no longer effective. Perhaps, however, this misconstrues the question, for probably it is not so much that the major companies believe that the dealers can arbitrarily determine the retail price level as that the dealers have previously believed that the major companies could do this and have insisted upon holding them responsible for retail price levels, and hence that it is better that the dealers should be allowed to find out for themselves the reality of the com-

petitive retail price-making forces. In any event, it would seem that in the end the conclusion will become fairly well established that under the competitive system retail prices are beyond the arbitrary control of either dealer or supplier, but are fixed by the competition among all types of marketers and by the fundamentals of supply and demand. When this conclusion is reached it is hard to see how the suppliers will have escaped from any responsibility they previously appeared to have for the width of dealer margins, because they will still be establishing the price *to* dealers and the difference between this and the actual retail prices will be the dealer margin. Furthermore, if experience in other lines of retailing is any index, retail dealers will be urging upon their suppliers efforts to maintain resale prices of their respective brands, so as to protect one retailer against the price cutting of other marketers handling the same kind of merchandise.

Some advocates of the Iowa Plan believe that by eliminating the practice of basing the dealer price on a certain amount or margin under the service-station price *whatever* it is, the price to dealers henceforth will be freed or insulated from the retail price level, instead of being borne down immediately when any reduction in the retail price takes place. But to suppose that the dealers' supplier in the face of reduced retail prices would fail to cut his price to dealers, to whatever extent seemed necessary to protect them, is to suppose that the whole nature of the industry has undergone a fundamental change. For it must be realized, we believe, that the typical major oil company regards its jobbers and dealers as its marketing representatives. As one authority puts it in a letter: "They (the major companies) frankly state that jobbers and dealers are their distributing facilities and that they will give them any margin that is necessary to keep them in business. . . . Under the Iowa Plan, therefore, while the tank-wagon price superficially may be somewhat more stable than the present marginal price, it will not be any unyielding Rock of Gibraltar. . . . When, under the Iowa Plan, competition among marketers cuts the realized price down to a point which would mean economic funerals among the dealers, their suppliers either directly or indirectly will protect them. There will be cutting of the tank-wagon price, either open or secret, or special concessions."

What, then, is the significance of the Iowa Plan? Being still from Missouri, we doubt that it represents any real solution of marketing problems. Yet it must certainly be considered as a response to some rather strong impelling forces. In a sense it is, we believe, a logical conclusion of developments that have been under way for a number of years. It has become trite to call attention to the overexpansion of oil-marketing facilities, and most people have sensed that in some way this overexpansion has been, at least in part, the result of ulterior forces rather than merely the attraction of marketing profits as such. We shall examine this

question further, but at this point we may say that the urge for marketing expansion originates largely in pressures and profits in other parts of the business.

Such an overexpansion of marketing made the costs of marketing very high. And the attempt to keep prices high enough and margins wide enough to cover these bloated costs created, in turn, a splendid opportunity for open price cutters in the form of trackage stations and the like. There developed, therefore, a conflict between prices and costs, focusing in the dealer and jobber margins. The margin must be wide enough to keep the overexpanded distribution facilities going; on the other hand, cut prices must be met or the necessary volume of business would be lost. Some major companies tried to solve the latter part of the dilemma by selling to the price cutters as well as through their own distribution systems.

The dealers and jobbers, like the independent refiners, however, have no ulterior motives for *their* operations; consequently they are interested solely in marketing and refining margins as such. The dealer demands a wide enough margin on which to operate and make a little money. The supplier says, "We cannot get the retail price high enough to give you the margin you would like to have." The dealer replies, "Then give me a cost price low enough so that at the retail price you think is necessary I will have sufficient margin." But this would often mean a dealer price so low as to leave no profit for refining or for the jobbing end of the business. Nevertheless, the independent marketer points out that on sales through its own operated stations the integrated company nets back, after deducting expenses, a far lower amount per gallon than that at which it sells to its distributors, and the latter says, "Give me that net back price and I will be satisfied."

More and more the independent distributor's attack has centered upon the allegedly subsidized marketing of the major companies through their own retail outlets. Some data on what the major companies' own retailing expenses have been are available from scattered sources. One of these is an analysis of Retail Distribution by Filling Station Chains, made by the Bureau of the Census for 1930. The figures covered a total of 864 chains operating 30,058 stations; 24,085, or approximately 80 per cent, of these were operated by sectional or national chains, presumably mostly integrated companies, the remaining 20 per cent being in local chains, defined as stations located in and around some one city. The expenses were not shown separately for the different types of chains, but we believe the proportion of major company-operated stations is so large that the figures may be considered representative of such operations.

The expenses reported amount to 23.77 per cent of sales. *These were the retail expenses only.* Quoting from the report, "It is strictly the operating expense of the stations and does not include tank truck transportation to the stations, nor central office administrative expense." It

did not include interest on capital invested, or on owned land, although 44 per cent of the stations were on owned rather than leased premises. The rent on the leased premises averaged 6.23 per cent of sales, or approximately 1.25¢ per gallon on gasoline sales.

Applying to gasoline sales the proportion of the total expense that such gasoline sales represented of the total sales (i.e., 85.02 per cent), it is found that to market the average gallon of gasoline through these stations cost about 4.90¢ a gallon³. If a reasonable amount were added for interest on owned stations, we believe it is safe to say that the total retailing cost per gallon would be around 5.5¢. Costs at 500 to 600 service stations operated by 10 oil companies in Cleveland in 1931, 1932 and 1933⁴ and for 117 stations in Allen County, Indiana, operated by dealers and companies in 1934⁵, showed average retailing expense applicable to gasoline of from 5.86¢ to 4.61¢ per gallon of gasoline sold.

In all of the cases studied it is notable that the costs of retailing applicable to gasoline were far higher per gallon of gasoline sold than the margins usually allowed to retail dealers, which ordinarily run from 3.5¢ to 4.0¢ a gallon.

As dealers have become more conscious of their position in the industry, the status of these high-cost, integrated-company retailing operations has become more and more embarrassing. Since the purpose of such retailing for many integrated companies evidently has not been primarily to make profits in marketing as such, the failure to make profits thereon has operated to only a negligible degree, if at all, to restrict the further expansion of service-station building by these same companies.

But however determined these companies may be to go on acquiring stations in order to have assured outlets and extra sales, it would be desirable to avoid some of the heavy losses on the operation of the stations if possible. Furthermore, to continue building more stations to be operated at a loss has the appearance of an untenable proposition, and one that naturally makes its sponsor highly vulnerable to political and semi-political attack by independent marketers that have entered the marketing field for the sake of making a profit in it. It should not, of course, be inferred from this discussion that no large company's marketing opera-

³ This being 23.77 per cent applied to an estimated price of 20.6¢ per gallon received for retail sales of gasoline in 1930; this price is based on 19.95¢ a gallon for regular grade gasoline (the average price shown in the A.P.I. index for 50 U. S. cities), and 22.95¢ for premium grade gasoline, estimated at 20 per cent of total sales, as reported in the *National Petroleum News* (Apr. 15, 1931) 95.

⁴ For Cleveland figures see brief of Labor Sub-Committee of the Planning and Coordination Committee under the Petroleum Code, entitled *Modification of Labor Provisions of Petroleum Code*, exhibits R-1, R-2 and R-3; or *Nat. Petr. News* (Sept. 5, 1934) 15.

⁵ For Indiana figures see Final Report of the Marketing Division of the Petroleum Administrative Board, 55, Table 4, issued in June 1936.

tions are profitable as such. A number of companies that came into the business originally as marketers or as marketers and refiners carry on marketing operations on a profitable basis.

But to return to the general status of integrated company retailing, we may summarize by saying that there have been several logical reasons for these companies withdrawing from direct salary operation of their retail outlets. First, to save money—a reason that becomes more important as gallonage per outlet declines, as wage and hour conditions for salaried employees become more rigid and chain-store and employee taxes tend to be added; second, to gain increased volume through the more flexible price policy of the individual dealer; third, to escape immediate responsibility for dealer margins; and fourth, to avoid criticism and attack on the vulnerable point of subsidizing unprofitable marketing operations.

To assume, however, that the Iowa Plan indicates that the integrated companies are retiring from marketing or that the Iowa Plan has solved their marketing problems in any important way, is unjustified. When major companies cease to build new stations and when they sell, not merely lease for short periods, the stations they already own, then, and not until then, will they have withdrawn from retailing. In the meantime, they have merely substituted a less expensive and perhaps a less burdensome and vulnerable method of operating the stations they do own. But it must not be overlooked either that one of the expenses of operating these retail stations will continue to be the difference between the integrated company's cost of owning and maintaining these stations (including interest on the investment, taxes, assessments, repairs, painting, depreciation, ground rent paid, administration, accounting, and all other expenses connected with these properties) and the rent received from the dealers to whom the stations are leased. This, we feel certain, is and will continue to be a very large item.

But if our analysis is true, there would seem to be little reason for a company whose retail operations are on a sound and profitable basis to adopt the Iowa Plan, albeit it may find it well worth while to lease a goodly number of its stations to capable and enterprising individuals.

Who Shall Supply the Capital Facilities for Marketing?

We have suggested that there is as yet no indication that major companies are withdrawing from the ownership of stations, but are continuing to build more stations. While there are no readily available statistics covering the last two years, it is a fair observation that, if anything, the major companies have spent or supplied more money for the building of new stations during the last two years than for any previous similar period in a long time.

So far as the general increase in the number of outlets during the last several years is concerned, that is evidenced by figures from the Bureau

of the Census. For 1929, the Bureau reported a total of 124,038 filling stations. In 1933, the Bureau's figure was 170,404. For 1935, a special census report indicated that the total had reached 196,649, an increase of about 15.4 per cent over 1933.

The investment of major companies in retail marketing is not, of course, limited to owned stations. It has included practically all of the storage and dispensing equipment for gasoline and oil at the dealer and other outlets handling these companies' products. The pre-N.R.A. voluntary Federal Trade Commission Code tried to limit the expansion of this practice by prohibiting it in areas where it was not already in vogue. To some extent this was nullified by the practice, which soon developed, of major companies leasing the larger dealer outlets and then re-leasing them to the dealer or making him the company's "agent," under which arrangement it was deemed proper for the supplying company to furnish pumps, tanks and other equipment. When the N.R.A. Code was adopted a broader prohibition on the loaning of equipment was included, but where loaned equipment was already installed it was allowed to remain and to be kept in good repair by the owner even to the point of being replaced with equipment of the same kind.

Since the expiration of the Code there has been considerable furnishing of new equipment. Thus far, however, such new equipment, which is very expensive, has been furnished principally to the more important dealer locations, and the question of who is to replace the equipment in the smaller dealer locations is still to be determined.

In addition to building stations of their own and furnishing pumps and tanks to dealers, the major companies have supplied considerable cash to dealers to finance improvements and new construction. Such money usually is loaned in connection with obtaining a mortgage and a long enough lease so that the major company is reasonably secure in getting its money repaid and in enjoying the dealer's increased business in the meantime.

We do not see, then, any evidence that major companies are supplying any smaller proportion of the capital put into marketing expansion than they formerly did. If anything, the proportion as well as the amount supplied by major companies probably is increasing.

What Shall the Price Structure Be?

One of the questions concerning price structures that has been in considerable confusion is what the jobber margin, or the relationship between the price to dealers and the price to jobbers, shall be. This margin has varied as widely as the views concerning it. In certain places within the last year or so, it has been as low as 1.25¢ a gallon; in other places as high as 2.50¢.

On the whole, the tendency seems to be for jobber margins to center around a figure of about 2¢ a gallon. This probably would mean a slight narrowing of the jobber margin as compared with the recent past, and in view of this and of the varying views and practices concerning jobber margins, it may be interesting to see what the jobber function consists of, what changes have occurred in it or are occurring, and how actual jobbing costs compare with the margin toward which we seem to be tending, of 2¢ a gallon.

Historically, the jobber function has been very clear, and whether it was performed by the jobber or by the major company, it was worthy of its hire. It consisted of receiving gasoline in tank-car lots, unloading it into bulk-station tankage and then rehauling it in small delivery trucks to retail dealers and to consumers taking tank-truck delivery. All this involved a rather substantial evaporation and handling loss. A similar warehousing and delivery function was performed with respect to motor oil and other merchandise. Usually the jobber function also included the furnishing of dispensing equipment to the dealer, keeping it painted and in good repair. It also included the maintenance of a selling force and it included advertising and sales promotion. Finally, it included the administrative, clerical, and collection work and the bad debt losses incidental to the performing of these selling, delivery and equipment-furnishing functions.

To what extent have changes taken place in the nature of the jobber function? The trackside station, to a limited extent, tended to eliminate the jobbing function, but the trackside type of marketing never was a potential substitute for more than a small part of the conventional type of marketing because the public as a whole could never have been served by trackside stations alone. The necessity of the jobbing function, as here described, being performed by someone, therefore, can hardly be controverted so far as the major part of the marketing job is concerned.

In warehousing and delivery have occurred and are occurring a number of changes that probably are rather far reaching. The old method of gasoline-out-of-tank-car-into-large-storage-out-into-small-inefficient-trucks is being supplanted by more modern methods. Most refinery suppliers, through additional refineries, gasoline exchanges, or water terminals, have major sources of supply much nearer their average jobber location than when shipments were made from relatively distant refinery points. There was little chance, then, of deliveries being made in transport trucks direct into bulk-station storage or into retail or consumer storage. More and more, however, the latter kinds of deliveries are becoming prevalent. With transport deliveries the jobber does not need to maintain as large storage facilities as formerly: the average transport holds only about one-half as much as a tank car, and this can be carried in several compartments. The lower bulk-station inventories thus made

possible reduce the investment in storage capacity and stocks, and lessen handling expenses.

Deliveries from bulk stations to retail and consumer outlets also have become less expensive. The modern truck is a light, speedy and economical vehicle compared with that of yesteryear, and through improved facilities more rapid loading and unloading is possible. Unfortunately, the small quantity that the average dealer can pay for at one time seriously reduces the economies that could be effected if the credit risk were not a factor.

No great change has occurred in selling, but there is a tendency to equip salesmen with panel delivery cars in which they can carry along and deliver many non-gasoline items. Some who have tried it believe this system makes for more efficient sales effort and real economies in delivery.

So long as the practice continues, of not furnishing new equipment to *all* dealers, there is a lessening in these costs; on the other hand, the new equipment is more expensive, so it is doubtful whether any permanent reduction can be counted on.

As for advertising, the expenditures by the average jobber have been considerably lessened, for, whereas he formerly tended to distribute under his own brand name and did his own advertising, he now typically handles the branded product of some major company which does most of the necessary advertising.

What, then, is the cost of performing the present-day jobbing function? The writer, in attempting to answer this, has examined a number of expense figures, among them those of a small jobbing company handling about a million gallons of gasoline annually. The total expense in 1936, covering all the items enumerated above, was approximately 1.65¢ per gallon of gasoline sold. Gasoline sales represented about 86 per cent of the total sales, and if the same proportion of the expense is attributed to the handling of the gasoline the expense per gallon was about 1.45¢. For another company handling about the same amount of gasoline the total expense attributable to gasoline handling was 2.35¢ per gallon of gasoline sold. For a much larger jobber operation, the expense in 1935 attributable to gasoline, on the same basis as worked out above, was approximately 1.38¢ per gallon. In all these cases the expenses included were those incurred only in performing the jobbing function and did not include expenses incurred for the operation, ownership or maintenance of any retail stations.

The foregoing figures should indicate the range of most jobber costs applicable to gasoline. There are always extremes at both ends, but prices and margins cannot cover all of the extremes. It seems fair to conclude that a well conducted jobber enterprise should be able to perform the jobbing function and have a reasonable profit left out of a margin of 2¢ a gallon between the dealer and jobber price. We believe that in

many instances the higher costs of which jobbers complain have been really incurred in the operation of their *retail* stations, many of which probably are costing a substantial amount in the way of net rent even though leased out to dealers.

Price Structure for Consumers on Tank-truck Deliveries

Another subject about which there is much conflicting thought at the present time is the relationship between distributors' prices and the prices to various types of consumers taking tank-truck delivery. One school of thought is that it is unfair for a refiner to make truck deliveries direct to a large consumer at a price below that charged to a dealer. Moreover, it is maintained that the price to commercial consumers, even very large ones, ought to be enough above the price to jobbers so that the latter would have a chance to sell such accounts.

The extreme case is the very large commercial consumer taking, let us say, transport deliveries of the most efficient sort, made direct from refinery or terminal, with no bulk-station handling or delivery in small retail trucks. The big commercial consumer has no interest in the refiner spending money to attract the ordinary passenger-car owner; furthermore, he need not be furnished with any elaborate storage and dispensing equipment. Often he has his own equipment and the style element is not important. The initial selling expense in connection with such business is low on a per gallon basis, and salesmen need not revisit such a consumer to acquaint him with sales-promotion material and so forth, and the credit of such a customer ordinarily would be good.

It is difficult to see why the prices to such consumers should not be considerably below the regular dealer's price. On the other hand, few if any of these savings apply to a small delivery to an out of the way consumer, where the gasoline may have to be carried, say in buckets, from a small tank truck into a barn or garage. For such a delivery the dealer price would seem to be too low.

It is difficult, therefore, to see how oil companies can escape the necessity of having a price structure for consumers taking tank-truck deliveries which, depending on quantity and method of delivery involved, will include prices ranging from somewhere near the tank-car or jobber price up to or above the dealer price.

How Much Rationalization Machinery Such as Codes and Legislation Is Needed?

In 1929, the industry adopted a voluntary code of marketing practices approved by the Federal Trade Commission, which was supplanted by the N.R.A. Code. Since the latter was declared invalid, the main effort of those particularly interested in code activities has been to get a new code approved by the Federal Trade Commission. Unlike the conditions

prevailing when the original code was adopted, however, various groups have now developed in the marketing end of the industry, causing greater difficulty in arriving at any unanimity of opinion as to what a new code should contain.

Other measures are under consideration, which might be termed rationalization efforts. One or two state legislatures are investigating the advisability of declaring oil marketing a public utility, with prices and other matters regulated. North Carolina is considering the operation of a state-owned gasoline terminal. Further development of the Robinson-Patman type of Federal legislation also is under consideration, including proposals to prohibit companies supplying resellers from selling direct to consumers and to divorce manufacturing from retailing. Most of these proposals probably represent an attempt at stabilization and at penalizing large-scale operations. While many of the proposals apply to industry generally, the oil business seems singled out for special consideration in some cases. Probably this reflects to some extent the unsettled condition of gasoline price structures and margins that has prevailed in various parts of the country during the last two or three years, and the efforts of those adversely affected to gain relief through legislative means. Perhaps the oil industry has not fully awakened to the vested interests on the part of jobbers and dealers that have been created through the tremendous marketing expansion that took place under the wide margins of former years. Any rapid change in price structure and margin conditions, therefore, that may seem economically sound must be tested also from the standpoint of its social and political wisdom, lest the measures intended to embody the very concept of free competition tend instead to destroy it.

It appears to us that it would be helpful if there were something in the way of a code that could provide an opportunity for all groups in the industry to discuss these matters and try to arrive at some definition of the basic factors involved in price structures and other marketing problems, and to give renewed support to the policy of publicly posted prices as contrasted with secret prices. This should not be viewed as an attempt to freeze the price structure into some given mold, but rather of enabling the industry to adjust its operations and customs to changing conditions in a more satisfactory and graceful manner than is likely to be possible without some such machinery.

WHAT ARE THE MAIN URGES TO MARKETING EXPANSION?

It is commonplace to point at the obvious overexpansion of marketing facilities in the oil business. Sometimes such overexpansion is attributed to the stupidity or overzealousness of marketing executives; this explanation is patently insufficient, since oil men are not different from other men.

We have suggested that in the developmental stage of the gasoline business margins were so wide as to attract much capital from independent marketers, who built individual stations or went into the jobbing business, or both. The wide margins of that period seemed attributable to the fact that demand for gasoline distribution was advancing more rapidly than it was being adequately supplied. But this reason long since ceased to exist, for not only are there now more than enough outlets for gasoline but the wide margins of former years have pretty much vanished.

The pressure of crude oil on the part of production companies that were not certain they could sell their crude at satisfactory prices and that felt it necessary therefore to go into refining and marketing also has been mentioned. Undoubtedly this crude-oil pressure was an important factor in former years, but it is doubtful whether under present-day production control many production companies are seriously concerned about their ability to dispose of their crude oil as such at satisfactory prices. The pressure of crude, therefore, does not appear to answer the continuing expansion of retail marketing facilities, which, as we have seen, is now being so largely financed by the integrated companies. It is clear, we believe, that not many of these integrated companies are making *marketing profits as such* on their present retail operations or investments, and we doubt whether they expect to do so on the new retailing facilities they are building or financing.

The obtaining of nation-wide distribution to improve the brand name and to obtain fuller advantage of national advertising programs is another reason sometimes suggested, but it would seem to fall somewhat short of being a satisfactory motive for investing more money in an already unprofitable type of operation.

Low Extra Cost of Additional Gallon as Motive

There is another possible explanation of this overexpansion phenomenon; that is, the low cost to an integrated company of getting the extra gallon of gasoline (or other oil products) to the point of sale, and, therefore, its great attractiveness. A consideration of the extra expenses incurred by an integrated company in getting this extra gallon to market indicates that they are so low, in relation to the average expense per gallon or to the aggregate expenses incurred serially by nonintegrated branches of the industry, as to make these last gallons extremely profitable to the integrated company.

So long as there is flush production, artificially restrained by production-control machinery, companies having production in flush areas can produce extra barrels of crude at a very low cost. It does not follow, of course, that a company's allowable production would be increased by its being able to use a larger volume of oil itself, but we believe there would be some general tendency in this direction. At any rate, the more oil

products a large company can sell and the more crude it can use, the larger the scale of its crude production operations can be, and a study of crude-oil costs indicates that on the whole the larger companies have lower crude-oil production costs than the smaller companies⁶. An analysis of the costs of production, by items of expense, also indicates that by far the greater part of the expense is indirect, especially in flush fields, but also in settled areas.

To what extent an integrated company can regard additional gasoline sales as a means of achieving lower over-all crude costs, and may, therefore, consciously or unconsciously, attribute a substantially lower than average crude cost to additional gasoline sales, we do not know. The answer depends upon the opinion of the integrated company in question as to its ability to sell extra crude oil as such at a satisfactory price, and as to whether its allowable production would or would not be increased by its having additional use for crude in its own operations. We believe it is safe to conclude, however, that to some extent some companies are influenced in the direction suggested.

Incremental Pipe-line Costs

It is in the pipe-line department that the low incremental cost theory finds its best support, for within the available capacity of a pipe line the extra cost of pushing through another barrel of crude oil or gasoline is an almost insignificant consideration. A study of over-all pipe-line costs, as reported to the Interstate Commerce Commission by most pipe-line companies, shows practically no relationship between total costs reported and volume of oil transported. In some cases where volume has increased the total costs have even gone down. We do not mean to suggest that costs are not increased by additional throughput, for of course they are, but it would appear that other items are more important in determining total expense than the throughput, within reasonable limits. The reason, of course, is plain. The only extra expense of any consequence is the extra pumping cost. A study of a number of the expense reports submitted to the Interstate Commerce Commission indicates that the direct pumping cost is less than $\frac{1}{2}\text{¢}$ per barrel per hundred miles. For a movement of, say, 700 miles—for example, as from Oklahoma to the Chicago area—the extra pumping cost would be only about 3.5¢ per barrel, or less than 0.1¢ per gallon.

It is interesting to compare this marginal or incremental cost on the last gallon with other costs and rates. A study of the costs reported by some of the major pipe lines running from the Mid-Continent to Chicago indicates that the average pipe-line cost per barrel for this movement is between 15¢ and 20¢ a barrel. The pipe-line tariff that

⁶ See Tables 86-90, U. S. Tariff Commission Report No. 30, Second Series, and Department of Interior Study of Crude Oil Costs 1931-34.

would be paid by an independent refiner on the last unit he shipped is about 40¢ a barrel, or approximately 1¢ a gallon on crude oil, and the pipe-line tariff on gasoline from Oklahoma points to Chicago is now, we believe, \$1.025 a barrel, or about 2.35¢ per gallon. The rail rate on gasoline from Oklahoma points to Chicago is about the same, and the gasoline price structure in general, of course, is based upon the costs of rail transportation.

If the element of low extra cost for the additional gallon applied only in the pipe-line department, it can readily be seen that the low costs of the extra gallon in this department alone would provide a strong incentive for an integrated company owning its pipe lines to seek additional sales of gasoline and to build new retail stations, if necessary, to get the extra gallons.

It might seem that these observations would apply only to extra capacity in a given pipe line already existing. The fact is, however, that the maximum capacity of a pipe line is a somewhat flexible quantity, for there are several ways in which pipe-line capacity can be stepped up (through additional pumping facilities or by adding additional lines for part of the distance between pumping stations) without requiring a completely new line. Of course the extra costs applicable to the extra business under such conditions would be higher than where no additional capacity was necessary, but even so it would be substantially less than the average cost of all oil through the line, and, of course, far less than pipe-line or rail tariff rates.

Refining Aspect

The company that has extra refining capacity can put through extra barrels of crude at an additional cost per barrel probably not in excess of one-half of the average refining cost per barrel. The exact ratio of additional to average costs will vary, of course, on account of many factors, including the question of whether royalties are paid, and if so, whether as an over-all amount or an amount per barrel processed. Probably most integrated refiners, however, would not be paying much royalty on a per barrel basis. The main expenses incurred, in refining extra crude within available capacity, are fuel, treating chemicals, and tetraethyl lead for gasoline, if so treated. To this would have to be added something to cover extra labor and repairs that might reasonably be attributed to the extra throughput and the possible impairment of by-product prices that might result from increasing their supply.

As for the question of being able to increase the refining capacity without building an entirely new unit, this would vary with the question of the limiting factors. Flexibility of capacity or ease of increasing it, however, would, we believe, be somewhat smaller than for pipe lines. It is true, however, that in building a refinery in the first place the capital

cost per barrel of extra capacity is much lower than the average cost per barrel, and the same would be true of the extra operating expense for running the extra throughput in the larger unit. Thus there is a temptation in building a refinery to make it somewhat larger than the business definitely in sight would require and the extra capacity then, in turn, provides the basis for the incremental cost factor here under discussion.

Marketing Aspect

When it comes to the jobbing or wholesaling end of the marketing operation, we believe the incremental factor is relatively low. The cost of selling and delivering the extra gallon is less than on the average gallon, to be sure, but the difference is relatively small as compared with the relative cost of the extra unit in the pipe-line or refining departments. For, generally speaking, distributors do not maintain more delivery trucks than they need to take care of the existing business, nor can additional accounts usually be added without directly adding to selling and equipment costs. The chief economy, therefore, would be in the small element of administrative and warehousing expense.

As for retailing, the marginal factor undoubtedly is very important—to the retailer. There are few stations that could not handle extra gallons with very little additional expense. Considering, however, that few integrated companies are still operating retail stations on a straight salary basis, they would not have much incentive to try to get extra gallons on account of the retailing margin as such. Their interest, for the most part, now ends with the sale to the jobber, retailer, or other customer taking tank-car or tank-truck delivery.

Let us see what the cost of the extra gallon, delivered to a dealer at some hypothetical point, on the basis of some of the factors we have been discussing, might be as compared with the full costs on which the price at the point in question might be based. For a determination of the latter, we may take the refinery price in Oklahoma of regular grade gasoline, which may be assumed as 5.75¢ a gallon; add to it a freight item of, say, 2.30¢ and a wholesaling margin of, say, 2¢—a total of 10.05¢ a gallon. Let us assume, for round numbers, that the price to dealers at such point is 10¢ a gallon, exclusive of taxes. At what cost, then, could an integrated company deliver to such point an extra gallon of gasoline?

If we assume no incremental cost factor in respect to crude but start out with a posted crude price of, say, \$1.10 a barrel and add to this one-half of the ordinary gathering charge on crude and one-half of the processing cost at the refinery, we might then assume a basic gasoline cost in Oklahoma of about 4.20¢ per gallon⁷. If to this we add the extra

⁷ Based on 1936 figures for refinery costs, as shown in footnote 2; adjusted for lower gathering and refining costs as described above.

pipe-line cost for transporting this extra gallon—i.e., about 5¢ a barrel, or, say, 0.15¢ per gallon—and if to this we add, say, 1.50¢ as the extra wholesaling cost on this extra gallon, we arrive at a total of 5.85¢ a gallon, or 4.15¢ under the 10¢ price. Should we use as a starting point the average crude oil *cost* of the integrated company instead of the crude oil *price*, probably we could deduct at least another cent from the delivered cost of the extra gallon, because such average *cost* of crude-oil production, we believe, would be more than 20¢ a barrel under the present selling price of crude.

From the foregoing figures it would appear that there is a tremendous temptation upon the integrated company to obtain some of these low-cost extra gallons even though the final realization for them had to be somewhat lower than on the average sales. Of course, if the extra gallons were sold at an outrightly lower price in such a way as to break down the entire price structure on all the gallons, the desirability of the extra gallons would be greatly reduced. It would seem logical then to expect to see extra gallons striven for in two ways: first, by actual *price* concessions in areas of the market where low prices were less likely to infect the whole market. Sales direct to large consumers, including governmental units and public utilities, would seem to come nearest to fulfilling these requirements, and it is indeed in connection with such sales, we believe, that low prices have been most prevalent. On the other hand, it would seem logical, in areas of the market where cut prices tend rapidly to infect the whole structure, to expect to see the extra gallon striven for through the creation of additional retail outlets rather than cut prices, and here again the facts seem to bear out the logic.

It may be questioned, however, whether the urge for the extra unit of sale is any greater in the oil business than in other industries. We believe it is, for a number of reasons. In the first place, the degree of integration is greater in the oil business, we believe, than in practically any other. Therefore, an integrated company desiring to obtain extra gallons on account of low incremental pipe-line or refining costs on such extra gallons can reach directly into the market for them by creating additional retail outlets.

In the second place, we believe the ratio of direct to indirect costs is smaller in several departments of the oil business than is generally true in industry. The best example of this is, of course, in the pipe-line division. The ratio of direct cost to total cost is low in most transportation operations; on railroads, for example, and especially in taxicabs, where the cost of hauling an extra passenger evidently is presumed to be nothing flat. With the exception of certain of the heavy-goods industries, such as iron ore, the oil industry is about the only one in which integrated companies within the business own the principal means of transporting the products. In industries for which the transportation

is performed by an outside agency, the cost to the shipper is the same on the last unit as on the first. The ownership of shippers by railroads was long ago eliminated, of course, by the Commodities Clause of the Interstate Commerce Commission Act.

If these observations as to the economics of the extra gallon are correct, we believe that this factor may be put down as a very influential one in helping to explain some of the price phenomena of our industry and the seemingly insatiable expansion of retail outlets in the oil business. This brief analysis and speculation has merely scratched the surface concerning this subject, of course; it is one that we believe would well warrant a good deal of further careful study and comparison with other industries.

World Consumption of Petroleum Products

By V. R. GARFIAS* AND R. V. WHETSEL,* MEMBERS A.I.M.E.

(New York Meeting, February, 1937)

It is estimated that during 1936 world consumption of petroleum, its products and related fuels reached an all-time peak of 1,757,778,000 bbl., an increase of 143,000,000 bbl. over 1935.

As indicated in Table 1, world output of petroleum and related fuels exceeded demand by 92,510,000 bbl. during the year, as compared to an excess output of 88,000,000 bbl. during 1935. Production within the United States exceeded domestic demand by approximately 51,000,000 bbl. in 1936, as compared to an excess output of 53,000,000 bbl. in the previous year. Outside the United States, production exceeded

TABLE 1.—*World Production and Consumption of Oil*
Thousands of Barrels

Year	World Production	World Consumption	Excess Production over Consumption	Excess Production over Consumption		Excess Imports over Exports, United States	Excess Imports from U. S. A. over Exports to U. S. A., World Outside U. S. A.	Total to Storage	
				United States	World Outside U. S. A.			United States	World Outside U. S. A.
1932	1,362,039	1,348,407	13,682	R-13,011 ^a	26,643	R-28,781	28,781	R-41,792	55,424
1933	1,467,128	1,406,923	60,205	67,427	R-7,222	R-60,254	60,254	7,173	53,032
1934	1,562,834	1,507,599	55,235	26,164	29,071	R-64,013	64,013	R-37,849	93,084
1935	1,702,793	1,614,475	88,318	53,027	35,291	R-75,474	75,474	R-22,447	110,765
1936 ^a	1,850,290	1,757,780	92,510	51,000	41,510	R-74,400	74,400	R-23,400	115,910

^a Estimated from statistics available in December.

^b R indicates "red figure."

demand by 41,510,000 bbl. in 1936 and by 35,000,000 bbl. in 1935, indicating that foreign output is making no progress toward curtailment in line with demand.

Table 1 also combines excess production in the United States with the favorable balance of exports over imports, showing that stocks in the United States were reduced by 23,400,000 bbl. in 1936, as compared to 22,447,000 bbl. in the previous year. In the rest of the world, excess output over demand combined with the excess of imports over exports from the United States indicates an unfavorable balance of approximately

Manuscript received at the office of the Institute Feb. 4, 1937.

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116,000,000 bbl. during 1936. Unquestionably a large portion of this balance represents an increase of stocks in foreign countries, but a part is also due to imperfect consumption figures and the impossibility of obtaining accurate production statistics from such countries as Russia.

Table 2 shows world production of crude and related fuels by countries and Table 3, the world's consumption classified by countries and according to principal products.

As the figures of the tables indicate, the petroleum industry within the United States showed some improvement during 1936. Withdrawals from storage, however, continue to be made possible by the favorable balance of exports over imports, but it must be emphasized that such favorable balance did not increase during 1936. In the world outside the United States, despite increased consumption the industry continued

TABLE 2.—*World Production of Crude Petroleum and Related Fuels*
Thousands of Barrels

Country	1935			1936 ^a		
	Crude	Related ^b Fuels	Total	Crude	Related Fuels	Total
United States.....	993,942	40,735	1,034,677	1,097,000	44,000	1,141,000
Russia.....	176,688	800	177,488	191,000	1,000	192,000
Venezuela.....	151,523	700	152,223	163,000	800	163,800
Rumania.....	61,150	900	62,050	64,000	1,000	65,000
Iran.....	57,304	870	58,174	57,400	900	58,300
Netherlands East Indies.....	42,569	1,800	44,369	44,500	1,800	46,300
Mexico.....	40,234	500	40,734	40,500	800	41,300
Iraq.....	26,500		26,500	28,200		28,200
Colombia.....	17,618	400	18,018	18,700	500	19,200
Peru.....	16,835	1,200	18,035	17,400	1,300	18,700
Argentina.....	14,317	300	14,617	15,200	400	15,600
Trinidad.....	11,670	90	11,760	13,200	100	13,300
British India.....	9,277	100	9,377	9,600	100	9,700
Germany.....	3,054	5,900	8,954	3,100	6,200	9,300
British Borneo.....	4,974	100	5,074	4,700	100	4,800
Poland.....	3,973	500	4,473	3,800	500	4,300
Bahrein Island.....	1,265		1,265	3,400		3,400
Japan.....	1,848	130	1,978	2,400	150	2,550
Sakhalin Island.....	2,850		2,850	2,840		2,840
Ecuador.....	1,725		1,725	1,850		1,850
Canada.....	113	1,334	1,447	130	1,350	1,480
Egypt.....	1,215	40	1,255	1,200	50	1,250
Others.....	1,050	4,700	5,750	1,000	5,120	6,120
	1,641,694	61,099	1,702,793	1,784,120	66,170	1,850,290

^a Estimated from data to December 1.

^b Related fuels: natural gasoline, benzol, alcohol blended as motor fuels, shale oils, et cetera.

to increase stocks rapidly, indicating the approaching necessity of the curtailment of foreign output and the possibility that exports from the United States may continue to decline.

TABLE 3.—*World Consumption of Petroleum Products
and Related Fuels^a*
Thousands of Barrels

Country	1934						1935		
	Motor Fuel	Kero-sene	Gas and Fuel Oil	Lubri-cants	Miscel-laneous	Total	Motor Fuel	Kero-sene	Fuel Oil
United States.....	410,399	44,233	340,371	18,484	106,678	920,165	434,897	47,652	366,514
Russia.....	12,759	27,489	53,568	7,710	15,774	117,300	14,205	29,010	59,102
United Kingdom.....	34,254	6,515	26,511	2,882	2,008	72,170	37,454	6,015	26,894
France.....	21,490	1,810	13,510	2,160	1,675	40,555	22,140	1,427	12,329
Canada.....	16,210	1,712	14,341	808	1,621	34,682	16,784	1,910	14,936
Germany.....	15,205	910	8,646	2,550	1,920	29,231	15,464	907	10,997
Japan.....	6,472	1,100	12,836	1,544	996	22,948	7,310	1,325	13,350
Argentina.....	5,503	1,132	13,066	293	792	20,786	5,816	1,217	14,943
Italy.....	4,003	1,410	7,000	552	1,379	14,374	4,213	1,309	9,522
Mexico.....	1,916	604	11,287	147	2,380	16,334	2,230	617	11,432
Rumania.....	782	1,351	11,667	206	1,680	15,686	786	1,231	11,212
Netherlands West Indies.....	172	23	11,486	29	2,140	13,850	180	27	11,811
British India.....	2,265	6,114	3,573	923	990	13,865	2,421	6,380	3,652
Australia.....	6,480	1,047	2,840	350	402	11,099	6,507	1,114	3,193
Netherlands East Indies.....	1,433	2,130	4,770	126	1,100	9,559	1,462	1,988	4,889
The Netherlands.....	3,280	1,453	1,965	312	610	7,620	3,310	1,790	2,275
Venezuela.....	517	20	738	21	4,945	6,241	561	26	928
Sweden.....	3,050	739	1,845	339	393	6,366	3,330	821	2,012
China.....	945	2,855	2,528	240	202	6,770	976	2,442	2,645
Brazil.....	2,250	724	3,010	163	38	6,185	2,461	738	3,169
Spain.....	3,547	113	2,297	205	419	6,581	3,628	231	1,898
Iran.....	404	915	3,111	186	1,387	6,003	420	962	3,160
Egypt.....	552	2,059	1,988	167	127	4,893	532	1,988	2,532
Union of South Africa.....	2,647	659	552	199	157	4,213	2,986	546	1,029
Denmark.....	2,151	618	1,732	200	236	4,937	2,164	533	1,561
Belgium.....	2,459	260	1,237	201	112	4,269	2,472	196	1,122
Cuba.....	541	72	3,643	38	62	4,356	482	68	3,692
Trinidad.....	120	70	2,282	30	280	2,782	101	72	3,659
Philippine Islands.....	860	580	1,822	98	104	3,464	982	549	2,253
Norway.....	980	276	2,089	77	88	3,510	1,162	297	1,886
Switzerland.....	1,857	195	1,155	145	21	3,373	1,831	191	1,142
Chile.....	619	56	1,424	37	15	2,151	622	55	2,560
New Zealand.....	1,847	115	1,185	69	83	3,299	1,821	152	1,164
Poland.....	809	1,000	364	401	359	2,933	961	992	568
Czechoslovakia.....	1,638	502	579	211	146	3,076	1,718	436	658
Iraq.....	322	205	1,310	41	320	2,198	285	214	1,948
British Malay.....	610	298	1,686	48	198	2,840	509	317	1,933
Hawaiian Islands.....	920	130	1,810	49	62	2,971	943	131	1,841
Austria.....	874	288	769	138	118	2,187	902	280	1,111
Uruguay.....	610	218	1,489	32	21	2,370	622	58	1,632
Panama Canal Zone.....	89	27	1,921	12	22	2,071	102	27	2,160
Algeria.....	1,201	394	301	113	91	2,100	1,261	392	312
Irish Free State.....	1,014	465	214	64	160	1,917	1,067	516	245
Peru.....	431	452	552	38	213	1,686	413	429	690
Greece.....	356	151	982	50	34	1,573	362	148	982
Porto Rico.....	460	67	871	27	26	1,451	480	70	920
Portugal.....	502	452	288	32	51	1,325	581	407	390
Hungary.....	439	441	577	77	81	1,615	407	396	443
Finland.....	582	337	131	86	79	1,215	561	356	128
French Morocco.....	764	101	81	41	92	1,079	757	91	99
Others.....	6,626	5,248	18,692	868	1,931	33,365	6,391	5,396	21,889
Total.....	586,126	120,134	602,292	43,829	154,818	1,507,599	620,092	124,442	651,382

^a Consumption figures include crude consumed as such and all its products; also related fuels such as benzol, natural gasoline and alcohol used as motor fuel. Oil delivered to ships' bunkers is included in consumption of country where deliveries were made.

^b All figures estimated from data available to December 1, 1936.

TABLE 3.—(Continued)

Country	1935 (Continued)			1936 ^b					
	Lubri- cants	Miscel- laneous	Total	Motor Fuel	Kero- sene	Gas and Fuel Oil	Lubri- cants	Miscel- laneous	Total
United States.....	19,598	112,989	981,650	482,000	50,000	405,000	22,500	130,500	1,090,000
Russia.....	8,150	16,910	127,377	14,800	30,400	63,200	8,500	17,800	134,700
United Kingdom.....	2,730	3,120	76,213	38,500	6,400	27,000	2,900	4,100	78,900
France.....	1,610	3,017	40,523	23,000	1,490	13,000	1,640	3,200	42,330
Canada.....	1,020	1,960	36,610	17,500	1,990	15,600	1,060	2,000	38,150
Germany.....	3,668	2,600	33,636	17,000	990	12,200	4,020	2,900	37,110
Japan.....	1,712	1,630	25,327	8,100	1,500	14,750	1,900	1,900	28,150
Argentina.....	416	812	23,204	6,200	1,320	16,400	450	890	25,260
Italy.....	658	1,924	17,626	4,500	1,480	11,000	720	2,200	19,900
Mexico.....	168	2,491	16,938	2,540	620	11,500	170	2,500	17,330
Rumania.....	213	1,878	15,320	790	1,240	11,700	220	2,000	15,950
Netherlands West Indies.....	32	3,267	15,317	180	30	13,200	35	3,820	17,265
British India.....	941	1,210	14,604	2,480	6,500	3,800	990	1,300	15,070
Australia.....	452	643	11,909	6,800	1,170	3,340	460	670	12,440
Netherlands East Indies.....	145	1,155	9,609	1,490	2,000	5,100	160	1,240	9,990
The Netherlands.....	366	841	8,582	3,480	1,830	2,400	380	890	8,980
Venezuela.....	29	5,591	7,135	590	30	1,200	35	5,900	7,755
Sweden.....	352	554	7,069	3,480	890	2,150	360	600	7,480
China.....	249	310	6,622	990	2,460	2,800	260	340	6,850
Brazil.....	172	62	6,602	2,510	750	3,280	180	70	6,790
Spain.....	271	532	6,560	2,800	190	1,650	100	210	4,950
Iran.....	190	1,431	6,163	430	980	3,200	200	1,500	6,310
Egypt.....	172	161	5,385	540	2,000	2,890	180	190	5,800
Union of South Africa.....	189	182	4,932	3,100	570	1,140	200	200	5,210
Denmark.....	151	271	4,680	2,200	560	1,640	160	290	4,850
Belgium.....	207	397	4,394	2,520	210	1,190	220	420	4,560
Cuba.....	38	101	4,381	490	70	3,750	40	110	4,460
Trinidad.....	29	272	4,133	105	70	3,800	30	290	4,295
Philippine Islands.....	70	117	3,971	1,000	580	2,400	80	130	4,190
Norway.....	89	97	3,531	1,190	305	1,980	95	110	3,680
Switzerland.....	156	36	3,356	1,830	190	1,150	160	40	3,370
Chile.....	69	32	3,338	650	60	2,750	75	40	3,575
New Zealand.....	72	106	3,315	1,990	160	1,240	80	115	3,585
Poland.....	392	302	3,215	970	1,010	600	400	300	3,280
Czechoslovakia.....	213	166	3,191	1,800	440	740	220	180	3,380
Iraq.....	48	613	3,108	310	220	2,080	55	690	3,355
British Malay.....	63	166	3,048	580	320	2,060	70	190	3,225
Hawaiian Islands.....	57	62	3,034	980	140	1,990	65	70	3,240
Austria.....	142	130	2,565	910	290	1,200	145	140	2,685
Uruguay.....	38	31	2,381	630	60	1,800	40	40	2,570
Panama Canal Zone.....	18	34	2,341	110	30	2,300	20	40	2,500
Algeria.....	106	121	2,192	1,300	400	340	110	130	2,280
Irish Free State.....	66	192	2,086	1,110	520	260	70	200	2,160
Peru.....	56	261	1,849	420	430	760	60	300	1,970
Greece.....	57	43	1,592	370	150	1,060	60	50	1,690
Porto Rico.....	32	36	1,538	490	70	990	35	40	1,625
Portugal.....	34	60	1,472	600	410	440	40	60	1,550
Hungary.....	81	92	1,419	420	400	450	90	100	1,460
Finland.....	90	91	1,226	580	360	140	95	95	1,270
French Morocco.....	33	122	1,102	770	95	110	40	130	1,145
Others.....	992	2,436	37,104	6,700	5,550	23,200	1,040	2,670	39,160
Total.....	46,902	171,657	1,614,475	674,825	129,930	707,920	51,215	193,890	1,757,780

Chapter V. Production

Introduction

BY JAMES TERRY DUCE,* MEMBER A.I.M.E.

In order to facilitate interpretation of the data in this chapter, we print the following excerpts from circulars to authors, compiled by Mr. Frank A. Herald when he was Vice-chairman for Production of the Petroleum Division:

Generally in Table 1 the unit for presentation of data is a field. For our purposes a field is defined as the whole of a surface area wherein productive locations are continuous. Such unit commonly includes and surrounds nonproductive areas. Such unit commonly includes a great variety of geologic conditions—several units of continuous productive reservoirs of distinctly different structure and of distinctly different stratigraphy. Therefore it is hoped that our authors will subdivide “field” so as to enable students to make analyses that may have scientific and/or commercial value.

As to each space in the tabulation, it is either (1) not applicable, (2) the proper entry is not determinable, (3) the proper entry is determinable, but not determinable from data available to the author, (4) the proper entry is determinable by the author. In spaces not applicable, the author will please draw horizontal lines; in spaces where the proper entries are not determinable, the author will please insert *x*; in spaces where the proper entries are determinable but not determinable from data available to the author, the author will please insert *y*; in spaces where the proper entries are determinable by the author he will, of course, make such entries. Generally, *y* implies a hope that in some future year a definite figure will be available.

Inability to determine precisely the correct entry for a particular space should not lead the author to insert merely *y*. Contributions of great value may be made by the author in many cases where entries are not subject to precise determination. In such cases the author should use his good judgment and make the best entry possible under the circumstances. For many spaces, the correct entries represent the opinion of the author (for example, “Area Proved”) and in such cases the entries need not be hedged to such extent as in cases where the quantities are definite yet can be ascertained only approximately by the author.

In cases under definite headings but where figures are only approximate, the author may use *x*. For example, if the total production of a field is known to be between 1,800,000 and 1,850,000, the author may report 1,8*xx,xxx*; or if the production is between 1,850,000 and 1,900,000, the author may report 1,9*xx,xxx*.

Where a numeral is immediately to the left of *x* or *y*, such numeral represents the nearest known number in that position.

As to quantity of gas produced from many fields the question will arise as to whether the figures should include merely the gas marketed or should include also estimates of gas used in operations and gas wasted. Although rough approximations

* Geologist, The Texas Company, New York, N. Y.; Vice-chairman for Production, A.I.M.E. Petroleum Division, 1936-1937.

may be involved, our figures should represent as nearly as possible the total quantity of gas removed from the reservoir.

While we have not provided a column for showing the thickness of the productive zone, generally the difference between average depth to bottoms of productive wells and average depth to top of productive zone will represent approximately the average thickness of the productive zone. For fields where this is not true because of unusually high dips, or for other reasons, it is suggested that the authors indicate in their texts the approximate average thickness of the productive zone.

The figure representing net thickness of producing rock should correspond to the total of the net portions of the producing zone which actually yield oil into the drill hole. It is recognized that for some fields the authors can make only rough guesses—so rough that figures would be of no value. In such cases the authors should enter either x or y , whichever is more appropriate.

We are particularly anxious to have every author give due consideration to the determination of structural conditions of each oil and/or gas body. Please consider each oil and/or gas reservoir and indicate its structure. The mere fact that a reservoir is on an anticline is not proof that the structural condition affecting the accumulation is anticlinal; for example, an oil and/or gas body limited by the upper margin of a lens on the limb of an anticline is "ML" as to structure. By all means, if the oil body occupies any position in the lens other than its upper limit, please so indicate clearly by footnote, for "ML" means, unless modified, that the accumulation is at the upper part of the lens. In every case where the oil and/or gas body terminates short of the up-dip continuity of the reservoir, please carefully check your evidence and then appropriately record your conclusion. "Terrace," "Nose" and "Syncline" are the only terms in our legend which presume such continuity.

Please note that the heading "Number of Dry and/or Near-dry Holes" is intended to cover only such holes as are within the limits of the defined fields.

In Table 2 are listed the important wildcat wells completed during the year. By the term "important" is meant: wells discovering new fields; wells resulting in the discovery of important extensions to old fields; wells discovering new zones in old fields; wells condemning important areas or resulting in significant stratigraphic information, even if the wells are dry; and exceptionally deep wells. At the foot of this table the total number of wells drilled in each district is given, segregated as to oil wells, gas wells and dry holes. The number of wells drilling on Dec. 31, 1936 are in two divisions, designated as wildcat wells and wells in proven fields.

FOOTNOTES TO COLUMN HEADINGS—TABLE 1

^a In areas where both oil and gas are produced, unless gas is marketed outside the field, such areas are included in column headed "Oil." Manufacture of casinghead gasoline and carbon black is interpreted as outside marketing of gas.

^b Wells producing both oil and gas are classified as "Producing Oil Only" unless gas from them is marketed off the lease.

^c W, water; G, gas; A, air; AG, air-gas mixture. Numbers following letters indicate numbers of injection wells.

^d Bottom-hole pressures are preceded by "e." All other figures represent pressures at casinghead with well closed.

^e P, paraffin; A, asphalt; M, mixed.

^f Cam, Cambrian; Ord, Ordovician; Sil, Silurian; Dev, Devonian; Mis, Mississippian; MisL, Lower Mississippian; MisU, Upper Mississippian; Pen, Pennsylvanian; Per, Permian; Tri, Triassic; Jur, Jurassic; CreL, Lower Cretaceous; CreU, Upper Cretaceous; Eoc, Eocene; Olig, Oligocene; Mio, Miocene; Pli, Pliocene.

^g S, sandstone; SH, sandstone, shaly; Ss, soft sand; H, shale; L, limestone; LS, limestone, sandy; C, chalk; A, anhydrite; D, dolomite; Da, arkosic dolomite; GW, granite wash; P, serpentine; O, oolite; Slt, siltstone.

^h Figures are entered only for fields where the reservoir rock is of pore type. Figures represent ratio of pore space to total volume of net reservoir rock expressed in per cent. "Por" indicates that the

reservoir rock is of pore type but said ratio is not known by the author. "Cav" indicates that the reservoir rock is of cavernous type; "Fis," fissure type.

ⁱ A, anticline; AF, anticline with faulting as important feature; Af, anticline with faulting as minor feature; AM, accumulation due to both anticlinal and monoclinical structure; H, strata are horizontal or near horizontal; MF, monocline-fault; MU, monocline-unconformity; ML, monocline-lens; MC, monocline with accumulation due to change in character of stratum; MI, monocline with accumulation against igneous barrier; MUP, monocline with accumulation due to sealing at outcrop by asphalt; D, dome; Ds, salt dome; T, terrace; TF, terrace with faulting as important feature; N, nose; S, syncline.

ⁱ Information will be found in text as indicated by symbols; A, name of author, other than above, who has compiled the data on the particular field; C, chemical treatment of wells; G, gas-oil ratios; P, proration; U, unit operation; R, references; W, water; O, other information.

Oil and Gas Development in South Arkansas in 1936

By H. K. SHEARER,* MEMBER A.I.M.E.

OIL production in South Arkansas in 1936, estimated to have totaled 10,654,940 bbl., showed a decline of 484,400 bbl., or a little more than 4 per cent from 1935. There are no proration restrictions, as practically all wells reached the pumping stage years ago. Although a new shallow field was discovered in Nevada County, and a deep producing horizon

TABLE 1.—*Oil and Gas Production in South Arkansas in 1936*

Line Number	Field, County	Age, Years to End of 1936	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas ²	To End of 1936	During 1935
1	El Dorado, Union.....	17	8,000	x	45,912,035	624,230
2	Irma, Nevada.....	16	820	x	5,932,170	321,160
3	East El Dorado ¹ , Union.....	15	1,420	x	8,816,575	187,625
4	Stephens, Columbia, Nevada, Ouachita.....	15	3,000	x	5,751,885	209,585
5	Smackover, Ouachita, Union.....	15	25,700	x	355,788,940	7,430,590
6	Heavy oil area, Ouachita, Union.....	15	16,000	x	306,965,615	6,605,320
7	Light oil area, Ouachita, Union.....	15	9,600	x	51,768,925	825,270
8	Snow Hill area, Ouachita.....	1	100	100	54,000	0
9	Bradley, Lafayette.....	12	80	0	186,705	0
10	Lisbon, Union.....	11	2,700	x	6,339,650	114,970
11	Champagnolle, Union.....	10	2,000	x	12,610,730	874,395
12	Mt. Holly, Ouachita.....	8	60	0	117,085	0
13	Urbana, Union.....	7	400	x	3,630,310	796,375
14	Garland City, Miller.....	4	300	0	1,430,325	555,410
15	Camden, Ouachita.....	2	10	0	32,525	24,000
16	Troy, Nevada.....	1	80 ¹	40	15,770	0
17	Total for oil fields.....		44,570	140	449,564,305	11,138,340

¹ Including other small producing areas.

² El Dorado, Irma, East El Dorado, Smackover, Lisbon and Champagnolle produced large quantities of gas from the tops of structures or the upper edges of sands in earlier years. Most of the gas was wasted, but some was used commercially. Stephens produced some gas from the Nacatoch and Urbana from the 2700-ft. sand.

Manuscript received at the office of the Institute April 9, 1937.

* Geologist, The Hunter Company, Inc., Shreveport, La.

opened at Snow Hill, Ouachita County, there was nothing in sight at the end of the year to indicate any increase in production. Deep wildcat drilling seems to have yielded results of more scientific than commercial importance.

There were 84 wells completed in 1936, a considerable decrease from the 123 completions in 1935, due principally to less drilling in the old fields. The 1936 completions included 26 oil wells, 3 gas wells and 55 dry holes. There were 43 wells drilled in wildcat territory, of which 41 were dry and 2 discovered new fields. Average depth of the wells drilled was much greater than in previous years, as 24 wells were more than 4000 ft. deep, including seven between 5000 and 6000 ft., four between 6000 and 7000 ft., and one over 7000 ft. Two wells, in Ouachita and Bradley Counties, were drilled through the "Permian" lime and into the underlying salt. The deepest well of the year, drilled near the Stamps fault in Lafayette County, was abandoned in porous oolitic lime, either lower Marine Trinity or Permian, at a total depth of 7707 feet.

TABLE 1.—(Continued)

Line Number	Total Oil Production, Bbl.		Total Gas Production, Millions of Cubic Feet	Number of Oil and/or Gas Wells								Depth, Average in Feet		Oil Production Methods at End of 1936			
	During 1936	Daily Average during Dec. 1936		To End of 1936 ²	Completed to End of 1936	During 1936		At End of 1936						Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells	
						Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas ³	Producing Gas Only	Total Producing	Flowing			Pumping	
1	582,835	1,560	x	1,112	0	16	10	224	0	0	224	2,177	{ 2,100 2,550 2,950	0	224		
2	307,770	765	x	142	0	0	5	73	0	0	73	1,179	{ 1,150 1,150	0	73		
3	188,830	455	x	187	3	3	7	59	0	2	61	2,180	{ 2,170 2,170	0	59		
4	214,005	600	x	303	0	0	12	186	0	0	186	2,110	{ 1,500 2,100	0	186		
5	7,252,095	19,850	x	3,731	7	47	91	1,809	5	0	1,814		{ 2,025 2,475 2,610 2,025 2,300	5	1,809		
6	6,404,000	17,455	x	y	2	26	80	1,249	0	0	1,249		{ 2,000 2,450 2,600 2,000 2,275	0	1,249		
7	794,095	2,065	x	y	0	21	11	560	0	0	560		{ 4,807 4,807 4,944 2,790	0	560		
8	54,000	330	y ³	5	5	0	0	0	5	0	5		{ 4,906 2,785 2,100 2,780 3,350	5	0		
9	0	0	0	6	0	1	0	0	0	0	0		{ 3,340 2,800 2,700 3,550	0	0		
10	105,985	275	x	356	0	1	8	142	0	0	142		{ 2,800 2,780 to 3,550	0	142		
11	979,525	1,975	x	225	10	5	4	84	0	0	84		{ 2,780 3,340 2,800 2,700 3,550	0	84		
12	0	0	0	6	0	0	0	0	0	0	0		{ 2,813 2,800 2,700 3,550	0	0		
13	675,055	1,555	x	41	2	1	2	30	0	0	30		{ 2,935 2,925 1,369 1,250 2,167	0	30		
14	325,045	520	0	27	2	4	0	23	0	0	23		{ 2,935 2,925 1,369 1,250 2,167	0	23		
15	8,025	15	0	1	0	0	0	1	0	0	1		{ 1,250 1,243 1,243 1,243 1,243	0	1		
16	15,770	470	y	5	5	0	0	4	0	1	5		{ 1,250 1,243 1,243 1,243 1,243	0	4		
17	10,654,940	28,040		6,142	29	78	139	2,635	5	3	2,643		{ 2,167 2,167 2,167 2,167 2,167	5	2,635		

^a Gas from the Snow Hill has been used for pumping operations in the Smackover field.

^b Footnotes for column headings and explanation of symbols are given on page 291.

The Reynolds well was drilled on a geophysically located high on the northeast flank of the Smackover structure. A deep test previously drilled near the high point of the Upper Cretaceous structure had found the limestone lower, but had shown porosity and salt-water saturation. Other wells in the Snow Hill area made only small producers of gas and light oil or distillate, and all soon started showing salt water. By the end of the year the five producing wells completed had made a total of only about 54,000 bbl. of oil, and were then producing about 300 bbl. of oil, 10,000,000 cu. ft. of gas and 1500 bbl. of salt water per day. So the operations as a whole were not profitable, and other "Permian lime" highs located by geophysical methods in Calhoun and Bradley Counties were drilled without finding production.

Troy.—The other discovery of the year was made in November, when the Benedum-Trees Oil Co., No. 1 Grove Land & Timber Co., in sec. 10, T. 14 S., R. 20 W., was completed pumping 450 bbl. per day from 2184 ft. By the end of the year five wells were completed, all in the same section, two producing 20° gravity oil from the Tokio sand of

TABLE 2.—*Summary of Drilling Operations in South Arkansas, 1936*

Important Wildcats Drilled in 1936										
County	Location			Total Depth, Ft.	Surface Forma- tion	Deepest Horizon Tested	Drilled by	Initial Production per Day		Remarks
	Sec.	Twp.	Rge.					Oil, U. S. Bbl.	Gas, Millions Cu. Ft.	
1 Bradley.....	12	17 S.	11 W.	5627	Claiborne	Permian salt	Phillips Pet. Co.			Dry.
2 Bradley.....	28	16 S.	12 W.	5195	Claiborne	Permian(?) lime	J. Modisette			Dry.
3 Calhoun.....	36	15 S.	14 W.	5519	Claiborne	Permian(?) lime	Ben. G. Barnett			Dry.
4 Chaloun....	22	15 S.	15 W.	4958	Claiborne	Permian(?) lime	T. R. Brown			Dry.
5 Columbia....	7	19 S.	18 W.	5401	Claiborne	Travis Peak	Burford & Co.			Dry.
6 Lafayette....	21	19 S.	24 W.	6009	Claiborne	Glen Rose	J. Modisette			Dry.
7 Lafayette....	20	16 S.	23 W.	7707	Claiborne	Permian(?) lime	Erwin & Leach			Dry.
8 Miller.....	9	20 S.	28 W.	6514	Claiborne	Glen Rose	Haynes Oil Corp.			Dry.
9 Miller.....	2	18 S.	28 W.	6288	Claiborne	Travis Peak	W. L. McClanahan			Dry.
10 Miller.....	2	17 S.	26 W.	5212	Claiborne	Glen Rose	Erwin & Leach			Dry.
11 Nevada.....	10	14 S.	20 W.	2190	Wilcox	Tokio	Benedum & Trees	450		{ Discovery well, Troy field.
12 Nevada.....	10	14 S.	20 W.	1236	Wilcox	Nacatoch	Benedum & Trees	41		{ Nacatoch discov- ery well, Troy field.
13 Ouachita....	27	15 S.	15 W.	4926	Claiborne	Permian(?) lime	Phillips Pet. Co.	208	13	{ Discovery well, Snow Hill area.
14 Ouachita....	27	15 S.	15 W.	5708	Claiborne	Permian salt	Phillips Pet. Co.	70	2	{ Deepest well, Snow Hill area. Completed at 4944 ft.
15 Union.....	13	17 S.	15 W.	6003	Claiborne	Travis Peak	J. C. Buckbee			Dry.

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1936.....	23	24
Number of oil wells completed during 1936.....	24	2
Number of gas wells completed during 1936.....	3	0
Number of dry holes completed during 1936.....	14	41

the basal Upper Cretaceous at about 2200 ft., two producing 15° gravity oil from the Nacatoch sand at about 1250 ft., and one producing gas from the Nacatoch. This area, which has been named the Troy field, is about 4 miles southeast of the Irma field, also producing heavy oil from the Nacatoch sand. Although still undefined, this is probably a small fault-line field of the same type as Irma.

Miller County.—At the close of 1936, the C. V. Lenz, No. 7 Dale, sec. 24, T. 15 S., R. 26 W., was showing for a producer, and has since been completed as a 50-bbl. pumper at a total depth of 4215 ft. The producing zone is 238 ft. below the Glen Rose anhydrite, this being the first lower Glen Rose production found in Arkansas. The structural conditions are not yet definitely known, and the importance of the discovery cannot be estimated until more wells are drilled.

ACKNOWLEDGMENTS

Information has been secured from the geological and scouting departments of various companies. Production statistics were obtained principally from the records of the Standard Oil Company of Louisiana—B. Peters, Chief Scout.

Developments in the California Oil Industry during the Year 1936

By V. H. WILHELM,* MEMBER A.I.M.E.

(New York Meeting, February, 1937)

THE year 1936 was a prosperous one for the oil industry in California. Increases in crude prices were posted in February and March. Re-establishment of voluntary curtailment in February was a factor in holding production at an efficient level throughout the year. Reduction of storage was effected through adherence to curtailment measures, aided by greater demand and smaller average well completions.

During the first six years of voluntary curtailment, allotments were increased during the summer season and reduced during the winter season. This year, good results were obtained through a revised system of allocation, by which the California monthly quota was held constant at approximately 540,000 bbl. per day. After a 7-month period of practically unrestricted production (ending in January 1936), numerous operators found that curtailment was still necessary, as California and export markets were not yet capable of absorbing the state's potential production, which was estimated to be in the neighborhood of 850,000 bbl. per day. Therefore, in February California operators again placed themselves under voluntary curtailment; with the result that state production dropped from around 700,000 bbl. per day in January to a low of 565,000 bbl. per day in April, and increased gradually to around 585,000 bbl. per day for December.

Drilling activity during the year increased about 10 per cent over that of the preceding year, although the resultant production per well decreased.

FIELD DISCOVERIES

As a result of a very active wildcatting campaign in California, aided by better interpretation of geophysical data, five new oil fields and two new gas fields were discovered.

Oil Fields

Greeley Field, Kern County.—The Standard Oil Co. added to its list of discoveries by drilling and completing its K.C.L. No. 11-1 well at a

Manuscript received at the office of the Institute Jan. 30, tables, Feb. 19, 1937.

* Chief Petroleum Engineer, The Texas Company (California), Los Angeles, Calif.

TABLE 1.—*Oil and Gas Production in California*

Line Number	Field, County	Age, Years to End of 1936	Area Proved, Acres		
			Oil	Oil and Gas*	Gas
1	Alamitos, Los Angeles.....	99½		110	
2	Athens-Rosecrans, Los Angeles.....	12¾		283	
3	Brea-Olinda, Orange.....	56		1,259	
4	Coyote East, Orange.....	25¼		682	
5	Coyote West, Orange.....	31		808	
6	Dominguez, Los Angeles.....	13½		810	
7	El Segundo, Los Angeles.....			890	
8	Huntington Beach, Orange.....	16½		1,890	
9	Inglewood, Los Angeles.....	12½		858	
10	Lawndale, Los Angeles.....	8½	15		
11	Long Beach, Los Angeles.....	15½		1,265	
12	Los Angeles, Los Angeles.....	33¾		840	
13	Monte Bello, Los Angeles.....	19½		1,180	
14	Playa del Rey, Los Angeles.....	7		640	
15	Potrero, Los Angeles.....	9½		88	
16	Richfield, Orange.....	17½		1,288	
17	Santa Fe Springs, Los Angeles.....	17½		1,240	
18	Seal Beach, Los Angeles.....	10½		400	
19	Torrance, Los Angeles.....	14½		3,650	
20	Whittier, Los Angeles.....	34¾		590	
21	Wilmington, Los Angeles.....	1½		x	
22	Capitan, Santa Barbara.....	7¼	360		
23	Elwood, Santa Barbara.....	8½		497	
24	Gato Ridge, Santa Barbara.....	5½	540		
25	Javon-Padre Canyon, Ventura.....	¾		200	
26	Moore Ranch, Santa Barbara.....	7			
27	Rincon, Ventura.....	9¼		360	
28	San Miguelito, Ventura.....	6½		320	
29	Santa Barbara, Santa Barbara.....	7¾		150	
30	Santa Maria, Santa Barbara & San Luis Obispo.....	34½		8,760	
31	Santa Maria Valley, San Luis Obispo.....	¾		700	
32	Casmalia, Santa Barbara.....	19½	850		
33	Cat Canyon East, Santa Barbara.....	25½	1,187		
34	Cat Canyon West, Santa Barbara.....	25½			
35	Edna Carroyo Grande, San Luis Obispo.....	26¾		270	
36	Huasna, San Luis Obispo.....	7		60	
37	Lompoc, Santa Barbara.....	32½	2,780		
38	Orcutt, Santa Barbara.....	34½		4,620	
39	Summerland, Santa Barbara.....	44	180		
40	Ventura Avenue, Ventura.....	20¼		2,120	
41	Ventura Newhall, Ventura, Los Angeles.....	72	4,135		
42	Bardedale, Ventura.....	42		510	
43	Conejo, Ventura.....	42		95	
44	Elsmera Canyon, Los Angeles.....	47	60		

* Footnotes to column heads and explanation of symbols are given on page 291.

TABLE 1.—(Continued)

Line Number	Area Proved Acres	Total Oil Production, Bbl.					Total Gas Production, Millions Cu. Ft.				
	Total	To End of 1936	During 1935	During 1936	Daily Average during Nov. 1936	To End of 1936	During 1935	During 1936	Maximum Daily during 1936 MCF		
1	110	1	757,095	662,909	1,751	1	1	1	1		
2	283	31,172,064	993,195	803,811	2,231	50,472	1,854	1,078	3,551		
3	1,259	157,158,584	3,611,804	2,960,753	8,050	75,754	3,556	2,839	9,033		
4	682	76,206,305	986,705	909,646	2,852	39,330	2,910	1,586	6,399		
5	808	71,805,228	3,553,712	3,033,973	7,847	137,603				13,669	18,119
6	810	87,471,941	7,915,850	9,712,179	25,317						
7	890	149,149		149,149	377						
8	1,890	246,043,505	15,133,293	13,247,499	35,102	245,888	22,652	20,718	68,760		
9	858	101,079,380	4,477,004	4,546,727	12,476	76,063	1,999	1,983	6,406		
10	15	478,623	64,196	49,307	105	1,111	123				
11	1,265	576,802,294	26,562,848	24,994,299	65,416	785,247	21,598	20,589	61,619		
12	840	65,153,052	292,123	303,778	817	y	y	y	y		
13	1,180	100,529,954	2,287,385	3,204,714	9,110	25,444	701	3,731	19,737		
14	640	38,001,659	5,695,942	4,643,658	10,986	39,695	7,561	6,366	22,659		
15	88	2,163,032	135,167	112,556	290	2,313	y	467	1,480		
16	1,218	79,963,169	2,803,703	2,443,126	7,096	72,199	2,259	2,044	6,265		
17	1,240	418,238,411	16,158,795	16,460,142	45,186	629,149	12,033	11,027	33,612		
18	400	75,649,222	2,623,431	2,800,317	7,008	83,559	2,508	4,195	16,412		
19	3,650	83,072,767	2,498,442	2,859,892	8,827	58,823	1,254	1,218	3,489		
20	590	16,992,286	379,047	346,633	930	366	y				
21	x		0	(97,742)	(440)						
22	360	1,395,655	521,528	570,727	1,796	635	203	432	2,098		
23	497	59,005,952	4,559,588	4,478,732	11,666	48,580	1,367	4,393	13,057		
24	540	(181,611) ²		(150,527)	(739)						
25	200	(108,836)	0	(108,836)	(427)						
26						5,034					
27	360	7,267,857	669,826	754,218	2,123	7,222	564	649	2,368		
28	320	1,812,154	296,286	580,170	2,214	1,044		1,044	8,243		
29	150	2,786,643	1,144,088	503,939	906						
30	8,760	134,780,466	1,531,370	1,668,174	5,325	32,053	1,646	1,502	4,450		
31	700		0	(61,621)	(443)		0				
32	850		(61,008)	(117,990)	(295)		y				
33	380			(13,232)	(17)						
34	807		(115,766)	(145,806)	(550)	2	2				
35	270		(53,131)	(95,492)	(178)						
36	60		y								
37	2,780		(86,459)	(85,521)	(260)						
38	4,620		(1,153,913)	(988,705)	(2,804)						
39	180	3,123,885	14,499	12,906	36						
40	2,120	175,833,336	10,979,450	12,609,878	34,309	632,619	31,610	38,701	123,343		
41	4,135	55,669,587	1,472,471	1,699,905	4,988	380	380				
42	510		(17,622)	(26,392)	(84)						
43	95		y								
44	60		y								

¹ With Seal Beach.² Figures in parentheses are not added in totaling. They cover small fields of which totals are included in groups, the group total only being used in the grand total.

TABLE 1.—(Continued)

Line Number	Number of Oil and/or Gas Wells								Drilling Data			
	Completed to End of 1936	During 1936		At End of 1936					Top of Shallowest Zone Ft.	Top of Deepest Zone Ft.	Productive Zones Ft.	Bottom of Deepest Productive Zone Ft.
		Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas ^s	Producing Gas Only	Total Capable Producing				
1				5		45		50	4,635	8,126	1,335	9,026
2	207	2		16		77		93	4,120	6,200	2,695	6,815
3	625	1	7	49		360		409	260	3,200	3,940	4,200
4	400	3	2	22		77		99	2,450	4,000	900	4,100
5		3		91		43		139	2,800	5,260	2,101	5,910
6		22		49		130		179	3,800	5,650	2,400	6,200
7	3	3	1			4		4		7,329	100	7,435
8	1,132	19	16	111		521		632	1,900	4,050	2,830	4,730
9	324	15	2	76		201		277	1,100	3,350	2,950	4,100
10	8		2		6			6		5,800	700	6,500
11	2,091	25	68	18		1,242		1,260	2,300	5,470	3,500	8,470
12	1,617		4			122		122	475	3,100	1,600	3,500
13	287	31	9	39		196		235	1,730	6,952	2,560	7,012
14	298	10	20	15		212		227	3,350	5,450	1,272	5,730
15	33		2	2		10		12	3,640	6,681	617	6,710
16	410	11	6	23		260		283	2,900	3,700	1,450	4,550
17	1,074	25 Includes Alamitas	22	70		633		703	3,470	7,500	3,260	7,850
18	241	4	1	34		56		90	4,350	6,200	1,980	7,100
19	938	55	10	27		533		560	2,700		500	3,200
20	290	Probably Torrance	3	17		158		175	250	3,900	2,000	4,200
21			(1)	(1)		(11)		(12)	2,400	3,122	1,100	3,648
22	40		3	15	25			40	1,150	2,510	350	2,580
23	101	6	1	4		78		82	3,164	4,325	410	4,385
24	With Santa Maria				(2)			(2)	1,750		800	2,550
25						3		3		5,230	270	5,500
26										4,139	354	4,493
27	48	1	4	7		29		36	2,500	2,950	650	3,550
28	10	Probably with Padre Canyon				6		6				
29	86					56		56		6,472	278	6,750
30	539	13	10			198		415	1,065		75	2,040
31				(7)		(1)		(8)	1,200	3,300	700	3,540
32				(44)	(10)	(54)		(54)				
33				(25)	(5)	(30)		(30)	2,800		400	3,900
34				(34)	(9)	(43)		(43)		3,500	300	3,100
35				(1)	(14)	(15)		(15)			200	3,700
36				(1)		(1)		(1)	800		400	1,200
37				(28)	(6)	(34)		(34)	2,200		700	2,900
38				(77)		(151)		(228)				
39	323			11	19			30	600	960	345	1,260
40	375	17		62		245		307	3,450	8,850	3,000	9,720
41	1,302	13	16	129		567		696				
42				(12)		(23)		(35)				
43				(53)				(53)				
44				(9)				(9)				

TABLE 1.—(Continued)

Line Number	Oil Production Methods at End of 1936			Character of Oil, Approx. Average during 1936			Producing Rock					Deepest Zone Tested to End of 1936	Estimated Oil Reserves, 1000 Bbl.	
	Number of Wells			Gravity A.P.I. at 60° F.			Name	Age ¹	Character ²	Net Thickness, Average in Feet	Structure ³	Depth of Hole, Ft.		
	Flowing	Gas-lift	Pumping	Maximum	Minimum	Weighted Average								
														Base ⁴
1			45	30	23	26	Puente	Mio						
2	2	15	60	40	30	35	Pico	Pli	SH	2,335		AF	9,054	
3		9	351	28	15	22	Pico	Pli	SH	2,695		A	7,591	
4			77	28	18	21	Puente	Mio	SH	3,940		AF	8,201	
5	1		47	32	27	29	Pico	Pli		900		A	9,084	
6	70	36	24	43	26	27	Puente	Mio	SH	2,100		A	8,144	
7	2		2	28			Pico	Pli	SH	2,400		A	8,992	
8	5	9	507	27	10	23	Puente	Mio	Congl. SH				7,477	
9	27		174	29	16	23	Pico	Pli	SH	2,830		MF	9,054	
10			6	32	26	29	Puente	Mio	SH	2,950		AF	6,508	
11	1	15	1,226	32	20	25	Pico	Pli	SH	700		A	7,405	
12			122	22	12	15	Puente	Mio	SH	3,500		AF	9,280	
13	10	3	183	38	14	26	Pico	Pli	SH	1,600		AF	y	
14	5	1	206	26	20	24	Puente	Mio	SH	2,560		AF	8,265	
15	2		8	45	34	38	Pico	Pli	SH	1,290		A	7,048	
16	1	2	257	28	15	21	Pico	Pli	SH	617		AF	8,376	
17	2	40	591	36	27	32	Puente	Mio	SH	1,450		A	5,933	
18	10	11	35	30	22	26	Pico	Pli		3,260		A	9,610	
19			533	27	14	19	Puente	Mio	SH	1,980		AF	7,969	
20			158	31	16	24	Pico	Pli	SH	500		A	5,938	
21			(11)	19			Pico, Puente	Pli-Mio	SH	2,000		MF	5,040	
22	9		16	44	20	32	Vaqueros, Sespe	Mio-Olig	SH	1,100		A	6,814	
23	4	19	55	39	34	36	Vaqueros	Mio	SH	350		A	4,071	
24			(2)	17	14	15	Sespe Monterey	Olig Mio	SH	480		A	7,157	
25	1	2		29.5		29.5	Pico	Pli	SH	800		Broken shale	6,510	
26	4	6	19	Gas	25	27	Vaqueros	Mio	SH	270		AF		5,000
27	4			31	25	27	Pico	Pli	SH	354		AF		
28	5		1	30	22	27	Pico	Pli	SH	650		AF		
29			56	20	17	19	Vaqueros	Mio	SH	278		AF	10,030	11,000
30	1		197	25	9	18			SH	75		MF	4,730	
31	(1)			16.4		16.4								14,000
32			(10)			9		Mio	SH	700		A	y	
33			(5)	y	y	y		Mio	SH	400		A	y	
34			(9)	y	y	14		Pli	SH	300		A	y	
35			(14)			14		Pli	SH	200		A	7,199	
36				y	y	y		Mio	SH	400		A	y	
37			(6)			19		Mio	SH	y		S	y	
38			(151)	25	10	17		Mio	SH	700		AF	y	
39			19	20	11	15		Mio	SH	706		AF	5,815	
40	98	45	102	33	28	30	Fernando	Pli	SH	345		AF	5,041	
41	2		565	40	12	x	Vaqueros Pico	Mio Pli	SH	3,000		D	10,569	
42			(23)	y	y	y	Sespe	Olig	SH	x		x	A	7,425
43				y	y	y	Vaqueros	Mio	SH	y		T	y	
44				y	y	y	Fernando	Pli	SH	y		A	y	
				y	y	y	Vaqueros	Mio	SH	y		A	y	

TABLE 1.—(Continued)

Line Number	Field, County	Age, Years to End of 1936	Area Proved, Acres		
			Oil	Oil and Gas ^a	Gas
45	Ex-Mission, Ventura.....	61	130		
46	Hopper Canyon, Ventura.....	48	80		
47	Modelo, Ventura.....	38	60		
48	Newhall, Ventura.....	47	160		
49	Pico Canyon, Los Angeles.....	61	75		
50	Sespe Canyon, Ventura.....	35		460	
51	Shiells Canyon, Ventura.....	25		350	
52	Simi Susanna, Ventura.....	24		596	
53	Sisar Silverthread, Ventura.....	51	330		
54	South Mountain, Ventura.....	20 $\frac{1}{2}$		725	
55	Sulphur Mountain, Ventura.....	9	40		
56	Tapo Eureka, Ventura.....	55	170		
57	Temescal, Ventura.....	12	235		
58	Timber Canyon, Ventura.....	38	110		
59	Tiptop Fresno Canyon, Ventura.....	18	50		
60	Torrey Canyon, Ventura.....	40	190		
61	Wiley, Los Angeles.....	49	60		
62	Watsonville, Santa Barbara, Santa Clara.....	50		100	
63	Half Moon Bay, San Mateo.....	50	80		
64	Los Gatos, Santa Barbara.....	$\frac{1}{2}$	20		
65	Sargent, Santa Clara.....	$\frac{1}{2}$	60		
66	Belridge, Kern.....	25 $\frac{3}{4}$		3,200	
67	North, Deep.....	6 $\frac{1}{4}$		} 1,600	
68	North, Shallow.....	24 $\frac{1}{2}$			
69	South.....	25 $\frac{3}{4}$			1,600
70	Coalinga East, Fresno.....	36			
71	Coalinga West, Fresno.....	35			
72	Coffee Canyon, Kern.....	3 $\frac{3}{4}$		500	
73	Edison, Kern.....	5 $\frac{1}{4}$		1,880	
74	Elk Hills, Kern.....	18		9,600	
75	Fruitvale, Kern.....	8 $\frac{3}{4}$	1,549		
76	Kern Front, Kern.....	24 $\frac{1}{2}$	3,320		
77	Kern River, Kern.....	36 $\frac{1}{2}$	9,633		
78	Kettleman Middle, Kings.....	5		980	
79	Kettleman North, Kings, Fresno.....	8 $\frac{1}{4}$		16,670	
80	Lost Hills, Kern.....	26 $\frac{3}{4}$	2,310		
81	McKittrick, Kern.....	39	1,525		
82	Midway Maricopa, Kern.....	35 $\frac{1}{2}$		48,117	
83	Mountain View, Kern.....	3 $\frac{1}{2}$		2,220	
84	Mount Poso, Kern.....	10 $\frac{1}{2}$	1,925		
85	Premier, Kern.....	10	1,220		
86	Round Mountain, Kern.....	9 $\frac{1}{4}$	1,340		
87	Ten Section, Kern.....	$\frac{1}{2}$		800	
88	Wheeler Ridge, Kern.....	14 $\frac{1}{2}$	295		
89	Buttonwillow, Kern.....	7			1,750
90	Tulare Lake, Kern.....	7			1,900
91	Devils Den, Kern.....	27	50		
92	McVan, Kern.....	4 $\frac{1}{2}$			

TABLE 1.—(Continued)

Line Number	Area Proved Acres	Total Oil Production, Bbl.				Total Gas Production, Millions Cu. Ft.			
	Total	To End of 1936	During 1935	During 1936	Daily Average during Nov. 1936	To End of 1936	During 1935	During 1936	Maximum Daily during 1936 MCF
45	130			(14,867)	(14,400)	(44)			
46	80			(37,454)	38,129	(93)			
47	60			y	(4,841)	(14)			
48	160			(57,863)	(43,194)	(109)			
49	75			(24,108)	(22,866)	(62)			
50	460			98,661	(100,650)	(264)			
51	350	(7,992,010)		(142,494)	(301,905)	(1,039)			
52	596			(44,429)	(39,213)	(118)			
53	330			(61,139)	(42,426)	(114)			
54	725	(19,106,510)		(591,843)	(685,247)	(1,878)	47,189	2,388	2,335
55	40			(5,619)	(3,489)	(11)			6,868
56	170			(14,820)	(11,898)	(35)			
57	235			(128,825)	(249,254)	(786)			
58	110			(18,891)	(17,324)	(29)			
59	50			(7,405)	(5,111)	(12)			
60	190			(52,003)	(51,216)	(143)			
61	60			(7,301)	(6,397)	(16)			
62	100	133,303		21,825	21,960	60			
63	80			y					
64	20			y	(8,363)	(24)			
65	60			y					
66	3,200	51,173,698	3,269,367	4,648,261	15,402	84,179			
67		(14,590,969)	(2,680,432)	(3,904,936)	(13,483)	13,929	36,606	128,636	
68	1,600	(15,880,626)	(32,994)	(12,027)	(50)				
69	1,600	(20,702,103)	(915,941)	(731,298)	(1,869)				
70	14,699	346,612,523	4,954,048	3,947,681	10,056				
71			2,295,369	2,119,398	5,676	1,093	43	36	117
72	500	With Round Mt.	582,320	1,450,486	4,672				
73	1,880	3,138,512	979,269	2,023,451	5,683				
74	9,600	138,374,463	3,216,318	3,194,445	8,270				
75	1,549	11,865,465	1,847,528	2,902,620	8,941	83,434	831	578	1,717
76	3,320	36,988,035	3,035,625	3,517,544	10,220				
77	9,633	268,930,077	1,482,484	1,645,180	4,305				
78	980	466,659	38,515	137,630	268	10,040	1,057	1,891	14,027
79	16,670	147,309,962	27,568,302	29,148,997	77,607	979,506	121,440	109,048	373,667
80	2,310	35,491,538	1,761,978	1,346,757	3,613		With Belridge		
81	1,525	85,739,444	1,393,985	777,420	1,764				
82	48,117	806,292,923	20,239,798	21,481,621	61,979	307,593	14,871	14,121	39,464
83	2,220	21,783,907	9,228,891	9,712,658	21,999	28,515	11,083	15,622	48,533
84	1,925	29,684,588	5,305,474	6,182,760	16,140				
85	1,220	861,000	234,414	564,450	1,882				
86	1,340	11,855,726	1,744,831	2,504,893	6,879				
87	800	188,464	0	188,464	1,181	2,969		2,969	14,488
88	295	3,349,050	152,846	128,962	343				
89	1,750	Gas				6,101	2,036		
90	1,900	Gas							
91	50		(704)	(11,848)	(95)				
92	y		(2,252)						

¹Lowest Flank 4200; bottom 4620 feet.

TABLE 1.—(Continued)

Line Number	Number of Oil and/or Gas Wells								Drilling Data			
	Completed to End of 1936	During 1936		At End of 1936					Top of Shallowest Zone Ft.	Top of Deepest Zone Ft.	Productive Zones Ft.	Bottom of Deepest Productive Zone Ft.
		Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas ^b	Producing Gas Only	Total Capable Producing				
45				(2)		(24)		(26)				
46				(3)		(10)		(13)				
47				(1)		(13)		(14)				
48				(8)		(35)		(43)				
49				(2)		(34)		(36)				
50				(8)		(22)		(30)				
51				(12)		(102)		(114)	602	2,700	1,800	4,200
52						(52)		(52)				
53				(5)		(66)		(71)				
54				(5)		(85)		(90)	1,000	2,200	3,200	3,400
55						(2)		(2)				
56				(1)		(22)		(23)				
57						(7)		(7)				
58				(1)		(10)		(11)				
59				(5)		(8)		(13)				
60				(1)		(40)		(41)				
61				(1)		(12)		(13)				
62	27					7		7				
63				11				11				
64				13				13				
65	847	11	2	120		196		316				
66												
67				(5)	(32)	(37)	4,917	8,000	980	8,530		
68				(11)	(8)	(19)	2,500	4,000	150	4,100		
69	1,915	5	55	(104)	(156)	(260)	1,000	4,000	570	4,500		
70												
71				367		244		611	100	2	420	520
72	With Round Mountain			164		577		741				
73	112	36	19			89		89	1,114		826	1,940
74	368			135		151		286	2,400	3,000	400	3,200
75	146	48	7	3	128			131	3,450	3,600	450	3,950
76	3,264	72	10	45	362			407	1,500		275	1,775
77				1,141	938			2,079	217		450	767
78	3	1	2			3		3		7,563	337	7,900
79	197	52	5	70		122		192	6,070	8,240	2,490	8,560
80	With Belridge	5	10	105	271			376	300	1,430	520	1,930
81	557	5	4	182	126			308	600	3,500	400	3,700
82	4,444	96	28	1,128		2,318		3,446	2,500	5,000	2,000	5,500
83	189	62	11					172		5,230	310	5,540
84	297	37	26	60	197	172		257	1,450	1,605	210	1,755
85		Also McVan		1	33			34	2,577		113	2,690
86	144	57	6	25	55			80	1,350	1,600	400	1,750
87	2	2	2			2		2				
88	With Midway Maricopa		1	8	26			34	1,700			
89	30					22		22	2,500	4,300	1,600	5,100
90	9							11	1,000		150	1,150
91				11		5		300	1,420		75	1,470
92				2				7	1,175		59	1,234

TABLE 1.—(Continued)

Line Number	Oil Production Methods at End of 1936			Character of Oil, Approx. Average during 1936			Producing Rock					Deepest Zone Tested to End of 1936	Estimated Oil Reserves, 1000 Bbl.
	Number of Wells			Gravity A.P.I. at 60° F.			Name	Age ¹	Character ²	Net Thickness, Average in Feet	Structure ³	Depth of Hole, Ft.	
	Flowing	Gas-lift	Pumping	Maximum	Minimum	Weighted Average							
45			(24)	y	y	y	{ Monterey Vaqueros Monterey Vaqueros	Pli		y	MF		
46			(10)	y	y	12		Mio	SH	y	S		
47			(13)	y	y	y		Mio	SH	y	A		
48			(35)	y	y	40		Mio			A		
49			(34)	y	y	y		Mio			AF		
40			(22)	y	y	y		Mio			ANS		
51	(2)		(100)	45	17	30	Sespe	Olig		1,800	ANS	7,423	
52			(52)	y	y	y	Sespe	Olig	SH		ANS		
53			(66)	y	y	y	Monterey	Mio					
54			(85)	33	19	24	Sespe	Olig	SH		AF		
55			(2)	y	y	y	Sespe	Olig	SH	3,200	A	5,922	
56			(22)	y	y	y	Monterey	Mio	SH		A		
57			(7)	y	y	y	Meganos	Eoc					
58			(10)	y	y	y	Vaqueros	Mio	SH		A		
							Vaqueros	Mio	SH		A		
							Vaqueros	Pli			MF		
							Monterey	Mio					
59			(8)				Sespe	Pli					
60			(40)					Olig	SH		AF		
61			(12)					Olig	SH		A		
62			7										
63													
64								Mio			S		
65			8					Mio	SH		A		
66	36		160										
67	(32)			42	13	27	Tembler	Mio					
68	(1)		(7)				Wagon Wheel	Eoc	SH	980	A	9,492	
69	(3)		(153)	27	17	22	Etchegoin	Pli	SH	150	A		
70			244	34	12	18	Etchegoin	Pli	SH	570	A		
							Tembler	Mio	SH	420	A		
							Santa Margarita	Mio					
71			577	34	12	18	Tembler	Mio					
72			58	17	16	16	Jacalitos	CreU	SH	420	MUP		
							Vaqueros	Mio	SH		FM		
73			89	28	14	20	Chanac	Pli					
							Tembler	Mio	SH	826	M	5,003	
74			151	38	15	27	Etchegoin	Pli	SH	400	A	8,404	
75	26		102	23	15	20	Kern River	Pli	SH	450	MF	4,542	
76			362	17	12	14	Etchegoin	Pli	SH	275	MF		
77			938	17	12	14	Etchegoin	Pli	SH	450	MF		
78	3			58	52	55	Kern River	Pli	SH	337	A		
79	84	37	1	66	35	38	Tembler	Mio	SH	2,490	A	10,249	
80			271	33	14	24	Etchegoin	Pli	SH	520	A	7,858	
81	1		135	22	12	17	Etchegoin	Pli	SH	400	AF	6,664	
							Etchegoin	Pli					
82	17	2	2,299	28	12	12	Santa Margarita	Mio					
							Maricopa	Mio	SH	2,000	MC	9,753	
83	47	7	118	34	25	28	Kern River	Pli	SH	310	MF	8,419	
84	1		196	17	15	16	Santa Margarita	Mio	SH	210	MF	3,130	
85			33	17	12	14	Vaqueros	Mio	SH	113	MF	2,943	
							Etchegoin	Pli					
86	1		54	22	16	19	Vaqueros	Mio	SH	400	MF	3,763	
87	2			61.5			Monterey	Mio	SH		A		32,000
88			26	25	22	25	Maricopa	Mio	SH		A	7,154	
89	22						Etchegoin	Pli	SH	1,600	D	4,946	
90							Tulare	Mio	SH	150		4,310	
91							Kreyenhagen	Olig	SH	75			
92			5	17	12	14							

depth of 7807 ft. on Dec. 22. The well, located in sec. 19-29-26, about 11 miles west of Bakersfield, is producing a zone from between the depths of 7738 and 7807 ft., all of which is solid Miocene oil sand. The initial production was at the rate of 2712 bbl. per day of 37.1° gravity oil cutting 15 per cent, through an $8\frac{1}{64}$ -in. bean. On a potential test, the well flowed 2657 bbl. per day of 36.7° clean oil through a $9\frac{6}{64}$ -in. bean, together with 2336 M. cu. ft. per day of gas. Careful interpretation of extensive geophysical work was responsible for the location of this well. Reserves of this new discovery should approximate those of the Ten Section field, 7 miles due south, which was discovered this year by the Shell Oil Company.

Padre Canyon, Ventura County.—In March, the Continental Oil Co. discovered the Padre Canyon oil field through the completion of its Hobson No. 1 well, flowing approximately 650 bbl. per day of 29.5° gravity oil. This field is on the westward trend of the Ventura Avenue fold. The productive area is estimated to be 200 acres, with a possible reserve of 5 million barrels. The structure is a long, narrow monocline, sealed by a fault.

Santa Maria Extension, Santa Barbara County.—During 1935, the Union Oil Co. drilled two wells in the Santa Maria Valley, a short distance southeast of the town of Santa Maria. These wells showed very small production of heavy-gravity oil, but subsurface data gained through the drilling of the wells indicated that greater productive possibilities might exist elsewhere in the vicinity. On this assumption, the Union Oil Co. drilled and completed its Adam No. 1 well on April 4, flowing 2376 bbl. of 16.4° gravity oil from a depth of 2576 feet.

TABLE 1.—(Continued)

Line Number	Field, County	Age, Years to End of 1936	Area Proved, Acres		
			Oil	Oil and Gas ^a	Gas
93	Pyramid Hills, Kern.....	$\frac{1}{12}$			
94	Newport, Orange.....	$12\frac{1}{2}$			
95	Tracy, Kern.....	$\frac{1}{7}$			
96	Deland, Kern.....	$\frac{1}{7}$			
97	Coleta, Santa Barbara.....	$\frac{1}{7}$			
98	Semi Tropic, Kern.....	2			
99	McDonald Isle, San Joaquin.....	$\frac{3}{4}$			
100	Rio Vista, Solano.....	$\frac{1}{2}$			
101	Greeley, Kern.....			800	
102	Other fields.....				
	Total.....				

The productive zone consists of Miocene (Monterey) sands and shales, which are sealed by overlap against the Franciscan formation. Production comes from both broken shales and oil sands. At the present time about 800 acres have been proved, and future development of other favorable acreage probably will bring the total productive area to over 1200 acres. No pipe line has been built to the field, consequently there has been no sustained production from the wells. The oil contains 25 per cent gasoline by cracking. The large production to be obtained in this field at shallow depths should be very profitable.

Ten Section Field, Kern County.—A number of wells have been drilled in California on structures located by reflection seismograph operations. The first oil discovery as the result of this work was that of the Shell Oil Co. with the completion of K.C.L. Stevens No. A-1 well in June, flowing 850 bbl. of 60.6° gravity oil, together with 13½ million cubic feet of wet gas. This production is coming from between the depths of 7800 and 7888 ft. The well revealed the existence of a major source of supply, and is located about 8 miles east of the Elk Hills field in sec. 29-30-26.

It is difficult to evaluate this discovery, but all available data indicate that the productive area will approximate 800 acres. The entire structure is apparently controlled by the Shell Oil Co. This is definitely a gas-cap field, and consequently production per acre is not likely to be very great. Nevertheless, since it is controlled entirely by one company, the field will undoubtedly be produced in such a way that the greatest possible recovery per acre will be obtained.

TABLE 1.—(Continued)

Line Number	Area Proved Acres	Total Oil Production, Bbl.				Total Gas Production, Millions Cu. Ft.			
	Total	To End of 1936	During 1935	During 1936	Daily Average during Nov. 1936	To End of 1936	During 1935	During 1936	Maximum Daily during 1936 MCF
93	y		(13,768)						
94	y	129,119	101						
95	y	Gas				448		448	14,454
96	y								
97	y	Gas							
98	y								
99	x	Gas							
100	x	Gas							
101	800	3,960		3,960					
102		4,670,178,576	207,832,131	214,773,315	582,077	845 4,602,517	298,127	845 327,180	3,122 1,114,502

The Shell Oil Company's K.C.L. No. A6, the second completion in this field, was brought in flowing 1600 bbl. of 36.4° gravity oil and 14 million cubic feet of gas per day from between the depths of 8315 and 8385 ft. This well was originally drilled to 8984 ft. and plugged back to 8385 ft. In an endeavor to obtain a low gas-oil ratio, all except 70 ft. of productive sand was blanked off. Drilling in this well indicated that possibly there is a maximum of 622 ft. of productive formations at the apex of this fold. Production is coming from the sands within the Miocene shales, the presence of which were not previously expected in such quantity.

Wilmington Area, Los Angeles County.—In previous years there has been scattered drilling north of Wilmington in the Los Angeles Basin, and small wells have been brought in from Pliocene sands containing oil of similar characteristics to that of the Torrance field. These wells were considered to have located an extension of the Torrance field.

During 1936, the General Petroleum Corporation drilled a well south of this area, close to the Los Angeles harbor. This well tested a zone in the Pliocene which produced 200 bbl. per day; then drilled through the Miocene until it encountered the underlying Franciscan schist, with the objective conglomerate zone present just above the schist. This conglomerate zone was devoid of showings, and was not tested. Tests of the deep Miocene zones showed very little production. However, on Dec. 8, the General Petroleum Corporation completed Terminal No. 1 well from the top of the Miocene formation for 1389 bbl. per day of 19.6° gravity oil, between the depths of 3120 and 3648 ft. This well delineated data that indicated a new field with a possible productive area of over a thousand acres. The most extensive sand is the top, or Pliocene sand.

TABLE 1.—(Continued)

Line Number	Number of Oil and/or Gas Wells								Drilling Data			
	Completed to End of 1936	During 1936		At End of 1936					Top of Shallowest Zone Ft.	Top of Deepest Zone Ft.	Productive Zones Ft.	Bottom of Deepest Productive Zone Ft.
		Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas ^b	Producing Gas Only	Total Capable Producing				
93				1				1				
94												
95	7	4	1					6				
96	7	2						3				
97	With Elwood											
98	35		1									
99	2	2	1									
100	1	1	1									
101	1	1				1	1	1				
102				4,702	2,186	10,012	32	16,932				

From drilling data, it is indicated that the Miocene sands, which contribute the production in the General Petroleum Corporation's well, will be very much less extensive than the overlying Pliocene productive horizon, but much more productive.

It is difficult to evaluate the reserves of this field, which apparently covers a very large area, but it is very probable that they will be similar to Torrance, and a reserve of over 40 million barrels of oil is indicated. This will be the most active field in the state during 1937.

Gas Fields

McDonald Island, San Joaquin County.—McDonald Island field, about 10 miles northwesterly from Stockton, was discovered by the Standard Oil Co. The discovery well was brought in on June 2, flowing over 26 million cubic feet of dry gas per day from a depth of 5227 feet.

Rio Vista, Solano County.—The Amerada Petroleum Co. discovered the Rio Vista gas field through the completion of Emigh No. 1 well, which produced over 80 million cubic feet per day of dry gas from a depth of 4485 ft. on June 19.

Northern and Central California.—To date there has been no sustained production of gas from gas fields discovered in northern and central California, but there is considerable indication that the dry gas reserves are not large.

DEVELOPMENTS IN PROVED AREAS

Bardsdale Field, Ventura County.—Efforts by various companies to locate productive measures in Eocene beds in the Ventura-Newhall

TABLE 1.—(Continued)

[illegible]

district have in all past instances been unfruitful. During this year, the Union Oil Co., drilling on its Dryden lease in the Bardsdale field, encountered the Eocene at approximately 5250 ft. Various tests of formations between 5250 and 6561 ft. (present depth of the well) have indicated a capacity of about 200 bbl. of 29.5° gravity oil per day. The low permeability of the productive sands indicates that the Eocene reserves in this field will not be large.

El Segundo Field, Los Angeles County.—During 1935, production was found by the Republic Petroleum Co. in the Los Angeles Basin east of El Segundo, in conglomerate between the Miocene shales and Franciscan schist. Two subsequent completions were small and not very profitable, considering the depth and expense of drilling.

TABLE 2.—*Summary of Drilling Operations in California*

Important Wildcats Drilled in 1936

	County	Location			Total Depth, Ft.
		Sec.	Twp.	Rge.	
		Survey	Lat.	Long.	
1	Alameda.....	13	3	3	5925
2	Fresno.....	35	21	17	8387
3	Fresno.....	30	16	15	6935
4	Fresno.....	31	21	15	2474
5	Fresno.....	36	21	14	2165
6	Kern.....	1	26	20	5904
7	Kern.....	3	31	29	5630
8	Kern.....	2	26	20	1143
9	Kern.....	2	26	20	7858
10	Kern.....	4	28	27	2840
11	Kern.....	14	30	28	5291
12	Kern.....	5	30	24	6149
13	Kern.....	4	30	29	3553
14	Kern.....	1	30	25	9000
15	Kern.....	36	11	19	5507
16	Kern.....	14	25	18	3509
17	Kern.....	5	28	20	4854
18	Kern.....	29	30	26	7888
19	Kern.....	2	26	20	6887
20	Kern.....	20	30	26	8900
21	Kern.....	11	28	27	2354
22	Kern.....	8	27	27	2064
23	Kern.....	34	27	28	2212
24	Kings.....	29	23	19	8825
25	Kings.....	28	22	20	5338
26	Los Angeles.....	20	4	13	6623
27	Los Angeles.....	33	3	14	6263
28	Los Angeles.....	33	3	14	7352
29	Los Angeles.....	13	4	13	6387
30	Los Angeles.....	4	5	13	6814
31	Los Angeles.....	27	4	13	3693
32	Orange.....	7	3	9	4796
33	Orange.....	7	6	10	3518
34	Orange.....	36	3	9	2714
35	San Joaquin.....	25	2	4	5227
36	Santa Barbara.....	11	5	35	2221
37	Santa Barbara.....	24	10	34	2576
38	Ventura.....	15	3	24	5501
39	Ventura.....	26	2	23	7635
40	Ventura.....	26	2	23	9384
41	Ventura.....	7	3	24	3432
42	Ventura.....	7	3	24	3922
43	Solano.....	26	4	2	4485

On Dec. 7, the Richfield Oil Co., drilling about $\frac{1}{4}$ mile southeast of the discovery well, brought in El Segundo No. 1 well, producing 2600 bbl. a day of 28.3° gravity oil. This well had considerably more oil-bearing zone in the conglomerate than the above-mentioned wells, which accounts for its very favorable completion. Considerable drilling is anticipated in this area, with the probability that at least 500 acres may be proved to be productive.

Kettleman Hills-North Dome, Kings and Fresno Counties.—Development at Kettleman Hills has been very active during the year, but performance of the field has not been similar to that of the usual California oil structure. It is usual for wells in California to have an increasing gas-oil ratio for a period of approximately six months, after which the

TABLE 2.—(Continued)

Important Wildcats Drilled in 1936								
	Drilled by	Initial Production per Day		Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks	Lease and Well Number
		Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing		
1	Seaboard Oil Corp.	32					Abandoned 12- 1-36	Johnson No. 1
2	Associated Oil Co.						Abandoned 3- 5-36	Whepley No. 5
3	Mohawk Pet. Co.						Abandoned 12-13-36	Langdon No. 1
4	Standard Oil Co.						Abandoned 8- 5-36	Camino No. 1
5	Standard Oil Co.						Abandoned 6- 1-36	South Coalinga No. 1
6	Associated Oil Co.						Abandoned 10-18-36	Taylor No. 1
7	Associated Oil Co.						Abandoned 10-31-36	Di Giorgio No. 2
8	Associated Oil Co.							Williamson No. 2
9	Associated Oil Co.							Williamson No. 1
10	Associated Oil Co.							Skinner No. 1
11	Associated Oil Co.							Nunez No. 1
12	General Petroleum Corp.							
13	Ohio Oil Co.	850	13.5	3 3/4	1850	2100	Dry hole 5-27-36	Doyle-McKeon No. 1
14	Ohio Oil Co.						Dry hole 9-15-36	Edison-Seale No. 4-1
15	Ohio Oil Co.						Dry hole 8-15-36	K.C.L. No. D-1
16	Richfield Oil Co.						Dry hole 8-17-36	Title Insurance & Trust No. 1
17	Shell Oil Co.						Dry hole 5-28-36	Alferitz No. 2
18	Shell Oil Co.						Dry hole 10-28-36	Voight No. 1
19	Standard Oil Co.							K.C.L. Stevens No. A-1
20	Standard Oil Co.							United No. 1
21	Union Oil Co.							K.C.L. No. 10-1
22	Union Oil Co.							Perseus No. 1
23	Union Oil Co.							Ford No. 1
24	Standard Oil Co.							Murdock No. 1
25	Union Oil Co.		Well No. 38-29-V					
26	Richfield Oil Co.		Giannini No. 1					
27	Shell Oil Co.		Kleinmeyer No. C-1					
28	Shell Oil Co.		Lloyd-Dabney No. 1					
29	Shell Oil Co.		McKenna No. 1					
30	General Pet. Corp.	1389					Amebo No. 1	
31	Gauthier Oil Co.	200					Terminal No. 1	
32	Continental Oil Co.						Completed 12- 7-36	
33	Shell Oil Co.						Completed 11-17-36	
34	Standard Oil Co.						Dry hole 5-18-36	
35	Standard Oil Co.						Dry hole 10- 6-36	
36	Union Oil Co.		26				Dry hole 5-28-36	
37	Union Oil Co.						Completed 6-2-36	
38	Continental Oil Co.	2376	0.4				Dry hole 4-17-36	
39	General Pet. Corp.	650					Dry hole 4-17-36	
40	General Pet. Corp.						Completed 4- 4-36	
41	General Pet. Corp.						Completed 2-20-36	
42	General Pet. Corp.						Dry hole 1- 8-36	
43	Amerada Pet. Corp.		80				Dry hole 9- 6-36	
							Dry hole 3-26-36	
							Dry hole 2-27-36	
							Completed 6-19-36	

ratio declines to a very small figure. Wells in Kettleman Hills, with a few exceptions, have an increasing gas-oil ratio; and decline in oil production is as yet along a straight line with but a slight tendency toward flattening of the curve. This is probably due to the fact that there has been no very great movement of edge water.

Average completions in the field are approximately 1200 bbl. per day of oil, with a definite declining tendency. In the future it will be necessary to estimate the production per acre of gas-cap fields at a much lower figure than the usual California water-drive fields.

Lost Hills Extension, Kern County.—For the last four years, activity at Lost Hills has been confined to exploration for deeper zones, and all efforts have been unsuccessful. Recently the Associated Oil Co., prompted by showings of oil in its abandoned deep test, Williamson No. 1, drilled a shallow well (Williamson No. 2) in an endeavor to locate the northward extension of the shallow zone. Up to this time this zone was productive only on the south plunge of the structure. Williamson No. 2 was completed on June 10 for 45 bbl. of 13.4° oil, and subsequently increased to over 300 bbl. per day. Later drilling indicated the presence of at least two more zones at shallow depths. The productive zones consist of oil sands on the flanks of the structure, which are overlapped at the top of the anticline. It is entirely possible that this newly discovered accumulation will extend over a narrow strip along the east flank of the structure for a considerable distance.

Midway-Sunset Field, Kern County.—Two new sources of crude supply were developed in this field during 1936: one, in what is now known as the "Williams Area" (in the south-central portion of the Midway-Sunset field), and the other, in the "Lakeview Area" (adjacent to the old Lakeview gusher in sec. 25-12-24). This new development has bolstered production of this field considerably, and has increased reserves to the extent of approximately 20 million barrels.

Mountain View Field, Kern County.—Activity in this field during 1936 tended to considerably enlarge the productive area and prove up approximately 640 additional acres. Also, the Mohawk Petroleum Co. drilled two wells about a mile from the southeast edge of the field and completed them as small producers from a new zone overlying the basement schist at approximately 6100 ft. This discovery will prove of considerable importance if this new horizon is found conformable to the oil measures now being produced in the Mountain View field.

Torrance-Redondo Field, Los Angeles County.—The Torrance-Redondo field was subjected to considerable development throughout the year. New production developed by the Dumas-Lewis Oil Co. adjacent to the westerly boundary of the old producing area caused rapid development of a previously restricted district, which was opened for drilling during the early part of 1936. Completions have ranged between 100 and

300 bbl. per day of 18° gravity crude, from 3300 to 3800 ft. Along the south side of this field, small production has been developed at a lower level by the completion of two wells from sands that lie between the depths of 4300 and 4550 ft. These new completions proved the contention previously entertained that deeper drilling would be profitable somewhere in the Torrance-Redondo series of folds.

IMPROVEMENTS IN DRILLING AND PRODUCING EQUIPMENT AND PRACTICE DURING 1936

Drilling

New surface equipment includes independent rotary drive and automatic feed controls. There has been a pronounced increase in the use of wire-line core barrels, especially on wildcat wells.

Controlled pressure drilling in low-pressure sands is still in the experimental stage. Development so far has not been very promising.

Technological aids to drilling include:

1. The use of thermometric surveys to determine height of cement outside casing and (still experimental) the logging of formations behind pipe by testing their thermal conductivity.

2. Electrical logging of formations in cased holes. This must also be considered as partly experimental, since results are often unreliable. The great need for these data is evidenced by the growing use of this service in spite of its lack of reliability.

3. The use of pressure recorders and maximum-reading thermometers on formation tests and water shutoff tests is yielding valuable information as to the productivity of formations.

Producing

Hydraulic pumps, long-stroke pumping units, and double-acting pumps have not as yet justified their early promise of meeting the problem of successfully lifting large quantities of fluid from deep wells.

A dynamometer, designed to be run on the pump itself, is giving valuable additional information on the behavior of the pump and in the analysis of pumping problems.

A device operating on the echo principle shows promise of providing a quick method of determining fluid level in wells, whether the well is on production or not.

The problem of completing wells in depleted oil sands, which are likely to be seriously mudded up during drilling, is being met by:

1. Keeping mud in good shape.

2. Use of chemicals during cleaning out to break down mud cake on the walls and permit fluid entry. This method has shown good results, although it is not uniformly successful.

3. Perforation cleaning tools run either on drill pipe or on bailers are having good results. Those working on the suction principle rather than on pressure are favored.

CONCLUSIONS

It is difficult to predict definitely the trend of production in California. In the past, it has been our experience that a price increase (which is normally expected in the spring) is invariably accompanied by the return to production of previously unprofitable wells.

During the year 1934, the average initial production was 1274 bbl.; during 1935, an average of 711 bbl., and during the first 10 months of 1936, an average initial production of 328 bbl. per day for the 1028 wells completed. This decline in the average initial production of new wells indicates that the rate at which we may expect to recover our oil reserves is diminishing during the present cycle.

Withdrawals from reserves during 1936 are estimated to be approximately 214 million barrels. Additions to reserves during the year by reason of new discoveries were somewhat less than this amount.

Despite these facts, it must not be considered that there will be an early shortage of crude in California, since other factors tend to offset their effect. In the first place, the natural demand for California oil will be considerably decreased by the normal trend of declining shipments to the Atlantic Coast and Atlantic foreign ports. These regions do not constitute natural markets for California oil, as greater supplies of oil at lower prices are closer to them. For years California producers have made strenuous efforts to stabilize their industry. At present there is proportionately less oil cracked in this state than in any other district in the country; but with increased demand for gasoline, the use of the cracking method can be so adjusted that the supply of gasoline available for market will take care of all demands for a considerable period in the future. Increased mechanical efficiency of automobiles will also tend to decrease consumption of gasoline.

As a result of this natural stabilization of the oil industry, we anticipate a very active and profitable year during 1937.

ACKNOWLEDGMENTS

The author wishes to thank Mr. H. W. Miller, Mr. E. L. Davis, and Mr. W. E. Remsen, of the Petroleum Engineering Division, The Texas Company, for their assistance and cooperation in preparing these statistics.

Oil and Gas Development in Colorado in 1936

By C. E. SHOENFELT, * MEMBER A.I.M.E.

THE discovery of oil in the Powder Wash structure in northwestern Colorado late in the fall of 1936 is the most important development in Colorado since oil was first discovered in the Moffat dome in the same county in 1923.

The Powder Wash structure gives promise of developing into an oil and gas field of major proportions and is of particular interest because the oil was found in Tertiary rocks of Eocene age, which heretofore had been productive in the Rocky Mountain region of gas only, and very few of the many structures of this kind have been tested because it was believed that oil production probably would be confined to rocks of Cretaceous age only, and these were, in most instances, at excessive drilling depths.

Powder Wash is one of a series of small domes in the belt of folds and faults on the south side of the large but shallow depression known as

TABLE 1.—Oil and Gas Production in Colorado

Line Number	Field, County	Age, Years to End of 1936	Area Proved, Acres				Total Oil Production, Bbl.			
			Oil	Oil and Gas ^a	Gas	Total	To End of 1936	During 1935	During 1936	Daily Average during Nov. 1936
1	Berthoud, Larimer.....	7		510		510	41,317	4,017	3,446	8
2	Boulder, Boulder.....	34	400			400	622,914	6,357	5,951	16
3	Florence-Canon City, Fremont.....	75	9,000			9,000	13,345,121	69,995	67,961	181
4	Ft. Collins, Larimer.....	13	400			400	2,041,702	26,544	23,391	70
5	Garcia, Las Animas.....	10			640	640				
6	Greasewood, Weld.....	6	200			200	433,759	26,981	18,924	34
7	Hamilton (Moffat), Moffat.....	13	400			400	5,197,682	150,703	150,327	434
8	Hiawatha, Moffat.....	9			3,180	3,180				
9	Iles, Moffat.....	12	600			600	5,346,187	1,027,901	1,164,540	2,698
10	Mancos Creek, Montezuma.....		40			40	3,816	724	218	0
11	Model, Las Animas.....	8			2,000	2,000				
12	Rangely, Rio Blanco.....	17	320			320	431,838	29,746	28,774	82
13	Tow Creek, Routt.....	12	200			200	1,472,050	65,864	63,636	173
14	Walden, Jackson.....	9	320			320	156,886	0	0	0
15	Wellington, Larimer.....	12	1,000		1,000	1,000	4,552,967	110,566	95,218	236
16	Total.....		12,880	510	5,820	19,210	33,646,239	1,519,358	1,622,386	

^a Footnotes to column heads and explanation of symbols are given on page 291.

Manuscript received at the office of the Institute April 12, 1937.

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the Washaki Basin. The oldest exposed rocks on the crest of the Powder Wash structure belong to the Wasatch formation of Eocene age. Green River beds with outliers of Browns Park beds are exposed on the flanks. According to W. T. Nightingale, who mapped the structure for the Mountain Fuel Supply Co., it has a closure of about 100 ft. The first well drilled by the Mountain Fuel Supply Co., in the northeast corner of sec. 5, 11 N., 97 W., was completed in Wasatch beds at a total depth of 2152 ft. It had an initial open-flow capacity of 34,000,000 cu. ft. of gas.

Oil was discovered Nov. 26, 1936, by the Mountain Fuel Supply Co. in a well drilled on the NE. SW. SE. of sec. 32, 12 N., 97 W., about $\frac{1}{2}$ mile north of the gas well mentioned above. When the well was first drilled in, it flowed at the rate of 60 bbl. of oil an hour from a sand in the Wasatch at 5014 to 5032 ft. On production test, through open tubing, it flowed at the rate of 47 $\frac{1}{2}$ bbl. of oil an hour. The oil is green in color and has a gravity on the A.P.I. scale of 39.9°. It has an exceptionally high wax content and congeals at 50° Fahrenheit.

One of the more important wildcats starting in Colorado at the end of the year is the Dry Mountain test of the Anderson-Kerr Drilling Co. and Phillips Petroleum Co. on the C. SE. SE. of sec. 19, 9 N., 99 W. Location for this test was released following the discovery of oil at Powder Wash. The well starts in Green River beds, estimated to have a thickness of from 600 to 800 ft. As Tertiary beds at Dry Mountain lie unconformably on the Lower Mancos, the depth to the objective Cretaceous oil sand, the Dakota, is estimated at 2000 feet.

TABLE 1.—(Continued)

Line Number	Total Gas Production, Millions Cu. Ft.			Number of Oil and/or Gas Wells							Depth, Average in Feet		Oil Production Methods at End of 1936		Pressure, Lb. per Sq. In. ^d					
	To End of 1936	During 1935	During 1936	Completed to End of 1936	During 1936		At End of 1936				Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells		Initial	Average at End of				
					Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Gas Only	Total Producing			Flow- ing	Pump- ing		1935	1936			
1	466.8	51	40.8	5	0	0		3	1	4	2,940	2,920			3		600	100	95	
2				53	1	1		8		8		2,000				8				
3				1,202	0	0		105		105		2,290				105				
4				15	0	0		11		11	4,560	4,535			11					
5	2,886	195	197	15	0	1	1		8	8		1,600						12	4	4
6				8	0	1		3		3				3						
7				23	0	0		12		12	3,880	3,860								
8	13,042.7	2,190	2,785.8	10	0	0		10		10	Sand Lenses									
9				37	1	0		32		32	3,315	3,295		16	15		850	800	785	
10				33 ¹	0	0		0		0		375			0					
11	19	0	0	6	0	0		0		0	1,004	960					25		12	
12				50	0	0	1	4		4		600			4					
13				17	0	0		15		15		2,600			15					
14				4	0	0		4		4	5,115	5,110								
15				31	1	0		22		22	4,500	4,480			22					
16	16,414.5	2,436	3,023.6	1,509	3	3	2	229	0	234				19	195					

¹ Field abandoned in 1936.

The Dry Mountain structure is the west dome in Colorado of a series of domes on the Uinta Mountain uplift, which trends in an east-west direction across northeastern Utah and northwest Colorado. It is formed in beds of Tertiary age with Green River on the surface and Browns

TABLE 1.—(Continued)

Line Number	Character of Oil, Approx. Average during 1936				Character of Gas, Approx. Average during 1936		Producing Rock							Deepest Zone Tested to End of 1936	
	Gravity A.P.I. at 60° F.			Name			Age ¹	Character ²	Porosity ³	Net Thick-ness, Aver-age in Feet	Structure ⁴	Number of Dry and/or Near-dry Holes to End of 1936	Name	Depth of Hole, Feet	
	Maximum	Minimum	Weighted Average		Base ⁵										
	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.													
1			38.5	P	1,120	0.09	Hygiene	CreU	S	20	A	4	Lakota (CreL)	4,031	
2			38.6	P			Pierre	CreU	H		MF	45	Morrison (Jur)	3,497	
3			31	P			Pierre	CreU	H		TS	1,097	Fountain (Pen)	1,875	
4	37		34.8	P			Muddy-Dakota	CreU	S	12	25	A	4	Dakota (CreU)	4,995
5					1,131	2	Benton	CreU	H			D	7	Morrison (Jur)	1,392
6			42	P			Muddy	CreU	S	9	35	A	6	Morrison (Jur)	7,040
7							{ Dakota	CreU		18 ³					
8			41	P			{ Sundance	Jur	S	14	20	D	11	Sundance (Jur)	4,490
9					1,080		Wasatch	Eoc	S	y	z	D		Mesaverde (CreU)	7,577
10			37	P			Sundance	Jur	S	9	20	D	5	Sundance (Jur)	3,447
11			40	P			Mancoes	CreU	S	y	y	ML	30	Dakota	1,280
12	52	42		P		2	Santa Rosa (?)	Tri	S	22	44	D	2	Fountain (Pen)	2,010
13			35	P			Mancoes	CreU	H			A	46	Weber (Pen)	7,173
14			50	P			Mancoes	CreU	H			A	2	Gneiss ⁶	5,310
15			37.4	P		4	Muddy-Dakota	CreU	S	14	90	AF	2	Morrison (Jur)	5,258
16							Muddy-Dakota	CreU	S	12	20	A	8	Sundance (Jur)	4,992

² Inert; 7.9 per cent helium.

³ Wells produce large quantities of CO₂ gas; not utilized at present.

⁴ Figures from recovery indicate 20°+.

⁵ Oldest sedimentary formation tested Thaymes (Triassic).

TABLE 2.—Summary of Drilling Operations in Colorado

Important Wildcats Drilled in 1936

	County	Location			Total Depth, Ft.	Deepest Horizon Tested	Drilled by	Initial Production per Day		Remarks
		Sec.	Twp.	Rge.				Oil, U. S. Bbl.	Gas, Millions Cu. Ft.	
1	Elbert	13	8 S.	57 W.	6004	Lakota	C. E. Lambert			Dry hole.
2	Larimer	6	11 N.	68 W.	3242	Ingleside	The California Co.			Dry hole.
3	Moffat	32	12 N.	97 W.	5032	Wasatch	Mountain Fuel Supply Co.	1140	5	
4	Prowers	15	23 S.	46 W.	5913	Mississippian	Trojan Oil & Gas Co.			Dry hole.
5	Washington	28	1 S.	49 W.	7005	Granite	Ind. Terr. Ill. Oil Co.			Dry hole.
6	Weld	21	8 N.	59 W.	6965	Dakota series	Continental Oil Co.			Dry hole.
7	Yuma	21	2 S.	43 W.	5595	Granite	Ind. Terr. Ill. Oil Co.			Dry hole.

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1936	4	1
Number of oil wells completed during 1936	14	1
Number of gas wells completed during 1936	1	0
Number of dry holes completed during 1936	4	15

Park beds exposed in an escarpment along the southwest side. The structure is believed to have a closure in excess of 500 feet.

At the close of 1936 four wells were actively drilling in widely scattered sections of Colorado; 14 wells were shut down for the winter; and three rigs were up. During the year nine wells were completed, adding 2760 bbl. of new oil and 16,550,000 cu. ft. of gas to the state's production.

ACKNOWLEDGMENT

The information contained in this report was obtained from weekly and monthly reports published during the past ten years by Petroleum Information, Inc., of Denver.

Oil and Gas Development in Illinois in 1936

BY ALFRED H. BELL,* MEMBER A.I.M.E.

(New York Meeting, February, 1937)

THE year 1936 in Illinois was marked by considerably increased activity in drilling, both wildcat and proved territory, in leasing, and in seismic and geologic exploration. Of the 92 oil and gas wells completed during 1936 in Illinois, 49 were oil wells, 3 were gas wells and 40 were dry holes. This compares with but 34 completions in 1935. The total of the daily initial productions of the new oil wells was 1755 bbl., or an average of 36 bbl. per well.

One new field was discovered, the Bartelso field in Clinton County.

The leasing of some large blocks of acreage in Clay, Marion, and other counties by the Carter Oil Co. in the late fall of 1935 was followed in 1936 by extensive leasing in southern Illinois by 10 major companies and many smaller companies and individuals. It is estimated that 2½ million acres were under lease by the end of 1936. Seismograph surveying has been carried on by about seven companies, and the number of seismograph parties operating in Illinois has varied from six to eight throughout most of 1936. It is estimated that approximately two million dollars has been spent in the state in seismic and geologic exploration and in leasing during the last quarter of 1935 and all of 1936.

Production of crude oil in Illinois in 1936, according to the Bureau of Mines, was as follows:

	BARRELS		BARRELS
January.....	325,000	July.....	402,000
February.....	294,000	August.....	380,000
March.....	396,000	September.....	386,000
April.....	347,000	October.....	393,000
May.....	389,000	November.....	363,000
June.....	383,000	December.....	387,000
			4,445,000

This 4,445,000 bbl. was an increase of 3 per cent over 1935. Although this increase was due largely to the fact that production was not artificially curtailed, it also reflects some new production and some increases in production from repressuring and water-flooding, which offset the

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TABLE 1.—*Oil and Gas Production in Illinois*

Line Number	Field, County	Age, Years to End of 1936	Area Proved, Acres			Total Oil Production, Bbl.	
			Oil	Gas	Total	To End of 1936	During 1935
1	Warrenton-Borton, <i>Edgar</i>	30	100	0	100	27,600 ±	550 ±
2	Westfield (Parker Twp.), <i>Clark, Coles</i>	32	9,000	55	9,055	x	x
3			850	75	925	x	x
4			9,000	0	9,000	x	x
5			1,500	0	1,500	x	x
6	Siggins (Union Twp.), <i>Cumberland, Clark</i>	30	3,580	75	3,655	x	x
7			3,135	55	3,190	x	x
8			435	15	450	x	x
9			855	105	960	x	x
10	York, <i>Cumberland</i>		310	40	350	x	x
11	Casey, <i>Clark</i>	29	1,925	55	1,980	x	x
12			190	15	205	x	x
13			400	0	400	x	x
14			1,525	15	1,540	x	x
15	Martinsville, <i>Clark</i>	29	710	155	865	x	x
16			15	20	35	x	x
17			275	35	310	x	x
18			105	0	105	x	x
19			170	0	170	x	x
20			195	0	195	x	x
21			5	0	5	x	x
22	North Johnson, <i>Clark</i>	29	1,320	20	1,340	x	x
23			1,115	0	1,115	x	x
24			160	0	160	x	x
25			820	5	825	x	x
26			215	0	215	x	x
27	South Johnson, <i>Clark</i>	29	1,715	65	1,780	x	x
28			185	5	190	x	x
29			295	0	295	x	x
30			1,675	35	1,710	x	x
31			845	5	850	x	x
32	Bellair, <i>Crawford, Jasper</i>	29	1,300	5	1,305	x	x
33			1,165	0	1,165	x	x
34			315	0	315	x	x
35			910	0	910	x	x
36	Clark County Division ¹		19,960	475	20,435	51,450,000 ±	479,000
37	Main ² , <i>Crawford</i>	30	35,135	515	35,650	x	x
38			340	0	340	x	x
39			33,795	510	34,305	x	x
40			1,000	0	1,000	x	x
41	New Hebron, <i>Crawford</i>	27	1,350	210	1,560	x	x
42	Chapman, <i>Crawford</i>	22	1,045	515	1,560	x	x
43	Parker, <i>Crawford</i>	29	1,310	30	1,340	x	x
44	Allison-Weger, <i>Crawford</i>	y	1,075	20	1,095	x	x
45	Flat Rock ³ , <i>Crawford</i>	y	1,375	545	1,820	x	x
46	Birds, <i>Crawford, Lawrence</i>	y	4,370	115	4,485	x	x
47	Crawford County Division ⁴		45,655	1,945	47,600	140,390,000	1,532,000
48	Lawrence, <i>Lawrence, Crawford</i>	30	24,150	1,550	25,700	x	x
49			5,015	35	5,050	x	x
50			2,240	0	2,240	x	x
51			345	1,095	1,440	x	x
52			15,960	220	16,180	x	x
53			4,020	200	4,220	x	x
54			6,950	0	6,950	x	x
55	St. Francisville, <i>Lawrence</i>	y	420	0	420	x	x
56	Lawrence County Division ⁵		24,570	1,550	26,120	219,343,000 ±	1,785,000 ±

¹ Total of lines 1, 2, 6, 10, 11, 15, 22, 27, 32.² Includes Kibbie, Oblong, Robinson and Hardinsville.³ Includes Swearingen gas.⁴ Total of lines 37, 41, 42, 43, 44, 45, 46.⁵ Total of lines 48 and 55.

natural decline in other areas. The price of Illinois crude oil was \$1.23 per barrel from Jan. 5, 1936, until the end of the year, an increase of 10¢ per barrel over that of 1935. This price rise has tended to check

TABLE 1.—(Continued)

Line Number	Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
	During 1936	Daily Average during Nov. 1936	To End of 1936	During 1935	During 1936	Maximum Daily during 1936	Completed to End of 1936	During 1936		At End of 1936				
								Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas ^b	Producing Gas Only	Total Producing
1	1,095	3.0	0	0	0	0	22	0	0	2	13	0	0	13
2	x	x	x	0	0	0	1,616	6	0	y	418	0	0	418
3	x	x	x	0	0	0	185	1	0	y	y	0	0	y
4	x	x	x	0	0	0	1,435	0	0	y	y	0	0	y
5	x	x	x	x	0	0	12	0	0	y	y	0	0	y
6	x	x	x	0	0	0	995	0	0	y	916	y	0	916
7	x	x	x	0	0	0	854	0	0	y	y	y	0	y
8	x	x	x	0	0	0	90	0	0	y	y	y	0	y
9	x	x	x	0	0	0	192	0	0	y	y	y	0	y
10	x	x	x	0	0	0	70	0	0	y	44	y	0	44
11	x	x	x	0	0	0	532	0	25	15	473	0	0	473
12	x	x	x	0	0	0	41	0	y	y	y	0	0	y
13	x	x	x	0	0	0	82	0	y	y	y	0	0	y
14	x	x	x	0	0	0	319	0	y	y	y	0	0	y
15	x	x	x	0	0	0	213	0	0	y	135	0	0	135
16	x	x	x	0	0	0	7	0	0	y	y	0	0	y
17	x	x	x	0	0	0	63	0	0	y	y	0	0	y
18	x	x	x	0	0	0	21	0	0	y	y	0	0	y
19	x	x	x	0	0	0	34	0	0	y	y	0	0	y
20	x	x	x	0	0	0	39	0	0	y	y	0	0	y
21	x	x	0	0	0	0	1	0	0	0	1	0	0	1
22	x	x	x	x	x	x	485	0	0	y	457	y	0	457
23	x	x	x	x	x	x	296	0	0	y	y	y	0	y
24	x	x	x	x	x	x	32	0	0	y	y	0	y	y
25	x	x	x	x	x	x	177	0	0	y	y	y	0	y
26	x	x	0	0	0	0	44	0	0	y	y	y	0	y
27	x	x	x	x	x	x	534	1	0	y	487	y	0	487
28	x	x	x	x	x	x	38	0	0	y	y	y	0	y
29	x	x	x	x	x	x	59	0	0	y	y	y	0	y
30	x	x	x	x	x	x	401	0	0	y	y	y	0	y
31	x	x	x	x	x	x	170	0	0	y	y	y	0	y
32	x	x	x	x	x	x	485	0	0	y	407	0	0	407
33	x	x	x	x	x	x	309	0	0	y	y	0	0	y
34	x	x	x	x	x	x	63	0	0	y	y	0	0	y
35	x	x	x	x	x	x	182	0	0	y	y	0	0	y
36	463,600	1,225	x	y	y	y	4,974	8	25	17	3,351	y	0	3,351
37	x	x	x	x	x	x	7,318	6	158	y	5,388	y	0	5,388
38	x	x	x	x	x	x	68	0	y	y	y	0	0	y
39	x	x	x	x	x	x	7,134	6	y	y	y	y	0	y
40	x	x	x	x	x	x	108	0	y	y	y	y	0	y
41	x	x	x	x	x	x	295	0	0	0	181	0	0	181
42	x	x	x	x	x	x	193	0	6	y	77	0	0	77
43	x	x	x	x	x	x	255	0	0	y	221	0	0	221
44	x	x	x	x	x	x	146	0	7	y	65	0	0	65
45	x	x	x	x	x	x	283	2	11	y	152	0	0	152
46	x	x	x	x	x	x	684	1	2	y	482	0	0	482
47	1,546,000	3,950	x	y	y	y	9,174	9	184	31	6,534	y	1	6,535
48	x	x	x	x	x	x	4,388	5	38	y	3,304	y	y	3,304
49	x	x	x	x	x	x	1,231	3	y	y	y	y	y	y
50	x	x	x	x	x	x	475	0	y	y	y	y	y	y
51	x	x	x	x	x	x	243	0	y	y	y	y	y	y
52	x	x	x	x	x	x	3,017	0	y	y	y	y	y	y
53	x	x	x	x	x	x	684	0	y	y	y	y	y	y
54	x	x	x	x	x	x	952	2	y	y	y	y	0	y
55	x	x	x	x	x	x	54	0	y	y	45	y	y	45
56	1,908,000±	5,017±	x	y	y	y	9,169	5	38	y	3,349	y	y	3,349

^b Footnotes to column heads and explanation of symbols are given on page 291.

TABLE 1.—(Continued)

Line Number	Depth, Average in Feet		Oil Production Methods at End of 1936			Pressure, Lb. per Sq. In.			Character of Oil, Approx. Average during 1936					Character of Gas, Approx. Average during 1936			
	Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells		Injection into Reservoir ²³	Initial	Average at End of		Gravity A.P.I. at 60° F. ²⁴					Sulphur Per Cent	Base ^a	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.
			Flowing	Pumping			1935	1936	Maximum	Minimum	Weighted Average						
1	215	159		13		x	x	x	x	x	x	y	y	x	x		
2				418		200±	x	x	38.4	28.3	34.0	y	M	x	x		
3	376	281		y		x	x	x	y	y	30.0	y	M	x	x		
4	446	334		y		x	x	x	y	y	33.5	y	M	x	x		
5	2,568	2,265		y		x	x	x	y	y	37.0	y	M	x	x		
6				916	A2	x	x	x	(36.9)	27.4	33.0	y	M	x	x		
7	465	367		y		x	x	x	y	y	34.0	y	M	x	x		
8	562	478		y		x	x	x	y	y	(33.6)	y	M	x	x		
9	590	556		y		x	x	x	y	y	(25.7)	y	M	x	x		
10	680	588		44		x	x	x	33.9	30.0	(30.3)	y	M	x	x		
11				473	21	x	x	x	37.2	27.2	29.2	y	M	x	x		
12	358	263		y		x	x	x	y	y	(31.9)	y	M	x	x		
13	426	309		y		x	x	x	y	y	(30.1)	y	M	x	x		
14	505	444		y		x	x	x	x	x	(33.6)	y	M	x	x		
15				135	A2	x	x	x	37.5	30.2	36.8	y	M	x	x		
16	411	255		y		x	x	x	y	y	y	y	y	x	x		
17	511	449		y		x	x	x	y	y	y	y	y	x	x		
18	506	477		y		x	x	x	y	y	y	y	M	x	x		
19	1,418	1,340		y		x	x	x	y	y	(38.9)	y	y	x	x		
20	1,596	1,553		y		x	x	x	y	y	(39.6)	y	M	x	x		
21	2,830	2,708		1		x	x	x	x	x	(39.6)	y	M	x	x		
22				457		x	x	x	36.2	27.2	31.0	y	M	x	x		
23	486	416		y		x	x	x	y	y	y	y	y	x	x		
24	451	314		y		x	x	x	y	y	y	y	y	x	x		
25	508	465		y		x	x	x	y	y	y	y	y	x	x		
26	554	534		y		x	x	x	y	y	y	y	y	x	x		
27				487		x	x	x	35.1	28.5	32.2	y	M	x	x		
28	549	392		y		x	x	x	y	y	y	y	y	x	x		
29	518	453		y		x	x	x	y	y	y	y	y	x	x		
30	570	489		y		x	x	x	y	y	28.5	y	M	x	x		
31	618	598		y		x	x	x	y	y	33.7	y	M	x	x		
32				407	AG2	x	x	x	35.6	27.3	(32.4)	y	M	x	x		
33	726	561		y		x	x	x	y	y	(37.0)	y	M	x	x		
34	907	817		y		x	x	x	y	y	y	y	y	x	x		
35	920	886		y		x	x	x	y	y	(37.0)	y	M	x	x		
36				3,351	22	x	x	x	39.6	25.8	33.0	y	y	x	x		
37				5,388	23	425±	y	y	36.8	25.1	33.0	y	M	960	2.5		
38	822	508		y		x	x	x	y	y	y	y	y	x	x		
39	960	900		y	24	425±	x	x	36.8	25.1	32.8	y	M	960	2.5		
40	1,416	1,337		y		x	x	x	y	y	y	y	y	x	x		
41	975	940		181	G2	x	x	x	35.0	24.3	30.1	y	y	x	x		
42	1,015	995		77	AG1	x	x	x	y	y	y	y	y	x	x		
43	1,025	1,000		221		x	x	x	y	y	y	y	y	x	x		
44	930	912		65		x	x	x	30.4	22.6	29.5	y	y	x	x		
45	945	935		152		x	x	x	26.6	20.1	22.5	y	y	x	x		
46	950	930		482	A7	x	x	x	34.1	26.5	31.3	y	y	x	x		
47				6,534	25	425±	x	x	38.6	18.5	32.5	y	M	960	2.5		
48				3,304	A1	650±	x	x	39.3	26.7	32.9	y	M	y	2.4		
49	1,000	800		y		x	x	x	y	y	y	y	y	x	x		
50	1,265	1,250		y		x	x	x	y	y	y	y	y	x	x		
51	1,345	1,330		y		x	x	x	y	y	y	y	y	x	x		
52	1,430	1,400		y		600±	x	x	y	y	y	y	y	x	x		
53	1,580	1,560		y		650	x	x	y	y	y	y	y	x	x		
54	1,710	1,700		y		x	x	x	y	y	y	y	y	x	x		
55	1,865	1,843		45		600	x	x	37.3	37.3	37.3	y	y	x	x		
56				3,349	A1		x	x						x	x		

^a Numbers in this column indicate numbers of injection wells.²¹ G1, A14.²² G1, AG13, A8.²³ G17, AG20, A42.²⁴ G17, AG20, A42.²⁵ G26, AG21, A42, W3.

²⁶ All gravities given (except those in parentheses) were from data for the year 1925 furnished by the Illinois Pipe Line Co. Gravities in parentheses are for particular samples; see Illinois State Geol. Survey Bull. 54, Table 3. The values have been converted from Baumé to A.P.I. gravities.

the abandonment of old wells, which had been increasing during the years of low prices (1931-1933). A preliminary estimate of the total value of the crude oil produced in Illinois is \$5,500,000.

TABLE 1.—(Continued)

Line Number	Producing Rock						Number of Dry and/ or Near-dry Holes to End of 1936	Deepest Zone Tested to End of 1936	
	Name	Age ¹	Character ²	Porosity ³	Net Thickness, Average in Feet	Structure ⁴		Name	Depth of Hole, Ft.
1	Unnamed	Pen	S	Por	<i>z</i>	ML	0	Pen Trenton	715 2,918
2	See below					D	101		
3	Shallow gas sand	Pen	S	Por	36	D	<i>z</i>		
4	Westfield lime	Mis L	L	Cav	<i>z</i>	D	<i>z</i>		
5	Trenton (Ordo)	Ordo	L	Por	<i>z</i>	D	<i>z</i>		
6	See below					D	28	Dev. limestone	2,010
7	First Siggins sand	Pen	S	Por	<i>z</i>	D	<i>z</i>		
8	Second and third Sig- gins sand	Pen	S	Por	<i>z</i>	D	<i>z</i>	MisL	960 808
9	Lower Siggins sand	Pen	S	Por	<i>z</i>	D	2		
10	York sand	Pen	S	Por	<i>z</i>	AM	<i>z</i>		
11	See below					AM	20		
12	Upper gas sand	Pen	S	Por	<i>z</i>	AM	5		
13	Lower gas sand	Pen	S	Por	<i>z</i>	AM	12	St. Peter	3,411
14	Casey sand	Pen	S	Por	<i>z</i>	AM	20		
15	See below					D	5		
16	Shallow sands	Pen	S	Por	<i>z</i>	D	1		
17	Casey sand	Pen	S	Por	<i>z</i>	D	5		
18	Martinsville sand	MisL	L	Por	<i>z</i>	D	1	Mis	965
19	Carper	MisL	S	Por	<i>z</i>	D	1		
20	"Niagaran"	Der	L	Por	<i>z</i>	D	3		
21	Trenton	Ordo	L	Por	<i>z</i>	D	1		
22	See below					AM	16		
23	Claypool sand	Pen	S	Por	<i>z</i>	AM	12	Mis	1,160
24	Shallow sands	Pen	S	Por	<i>z</i>	AM	4		
25	Casey sand	Pen	S	Por	<i>z</i>	AM	12		
26	Upper Partlow	Pen	S	Por	<i>z</i>	AM	16		
27	See below					AM	29		
28	Claypool sand	Pen	S	Por	<i>z</i>	AM	3	MisL	1,471
29	Casey sand	Pen	S	Por	<i>z</i>	AM	11		
30	Upper Partlow	Pen	S	Por	<i>z</i>	AM	29		
31	Lower Partlow	Pen	S	Por	<i>z</i>	AM	10		
32	See below					AM	14		
33	"500 Ft." sand	Pen	S	Por	<i>z</i>	AM	3	Trenton (Ordo)	4,620
34	"800 Ft." sand	Pen	S	Por	<i>z</i>	AM	3		
35	"900 Ft." sand	MisU	S	Por	<i>z</i>	AM	12		
36					33±		213		
37	See below					ML	202		
38	Shallow sand	Pen	S	Por	<i>z</i>	ML	<i>z</i>	Trenton (Ordo)	4,620
39	Robinson sand	Pen	S	Por	25±	ML	167		
40	Oblong	Mis	S or L	Por	<i>z</i>	A, ML	23	Mis	1,479
41	Robinson sand	Pen	S	Por	<i>z</i>	ML	5	Mis L	2,056
42	Robinson sand	Pen	S	Por	<i>z</i>	ML	10	Mis	2,279
43	Robinson sand	Pen	S	Por	<i>z</i>	ML	10	Pen?	1,127
44	Robinson sand	Pen	S	Por	<i>z</i>	ML	6	Pen	1,041
45	Robinson (Flat Rock)	Pen	S	Por	<i>z</i>	ML	8	Pen	1,032
46	Robinson sand	Pen	S	Por	<i>z</i>	ML	12	MisL	1,731
47		Pen, Mis	S	Por	<i>z</i>	ML	251	Trenton (Ordo)	4,620
48	See below					A	84	St. Peter	5,190
49	Bridgeport sand	Pen	S	Por	40	A	19	Mis St. Peter	1,900 5,190
50	Buchanan	Pen	S	Por	15	A	3		
51	"Gas" sand	MisU	S	Por	15	A	5		
52	Kirkwood	MisU	S	Por	30	A	10		
53	Tracy	MisU	S	Por	20	A	11		
54	McClosky	MisL	L	Por	10	A	24		
55	Kirkwood	MisU	S	Por	22	ML	0		
56							84		

In most Illinois fields the 1936 oil production differed only slightly from that of 1935. Slight increases took place in Crawford and Lawrence Counties and slight decreases in Clark and St. Clair Counties, no change in these counties being greater than 3 per cent. Production from the Colmar-Plymouth oil field, McDonough and Hancock Counties, nearly doubled, because of air repressuring. The Marion County district of the Illinois Pipe Line Co., which includes the old Carlyle, Sandoval, Wamac

TABLE 1.—(Continued)

Line Number	Field, County	Age, Years to End of 1936	Area Proved, Acres			Total Oil Production, Bbl.	
			Oil	Gas	Total	To End of 1936	During 1935
57	Allendale, Wabash.....	24	1,670	0	1,670	4,220,000 ±	280,000 ±
58	Total Southeastern Illinois Field ⁶		91,845	3,970	95,815	415,403,000	4,076,000
59	Colmar-Plymouth, Hancock, McDonough.....	23	2,450	0	2,450	2,140,000	86,800
60	Pike County Gas, Pike.....	31 ⁷	0	8,960	8,960	0	0
61	Jacksonville Gas, Morgan.....	26	30	1,290	1,320	2,100	0
62	Carlinville, Macoupin.....	27 ¹⁰	30	50	80	x	0
63	Spanish Needle Creek, Macoupin.....	21 ¹¹	0	80	80	0	0
64	Gillespie-Wyen, Macoupin.....	21	40	0	40	x	1,925
65	Gillespie-Benid Gas, Macoupin.....	13 ¹²	0	80	80	0	0
66	Staunton Gas, Macoupin.....	20 ¹³	0	400	400	0	0
67	Litchfield, Montgomery.....	57 ¹⁴	100	0	100	22,000	0
68	Collingsville, Madison.....	27 ¹⁵	40	0	40	715	0
69	Ayers Gas, Bond.....	14	0	320	320	0	0
70	Greenville Gas, Bond.....	26 ¹⁶	0	160	160	0	0
71	Carlyle, Clinton.....	25	915	0	915	3,289,000 ±	39,500
72	Frogtown, Clinton.....	18 ¹⁷	300	0	300	z	0
73	Sandoval, Marion.....	27	770	0	770	2,607,000 ±	27,000 ±
74	Centralia, Marion.....	26	175	0	175	z	y
75	Wamac, Clinton, Marion, Washington.....	15	250	0	250	353,000 ±	35,000 ±
76	Dupo, St. Clair.....	8	670	0	670	877,600	51,500
77	Waterloo, Monroe.....	16 ⁷	125	0	125	166,000	0
78	Sparta Gas, Randolph.....	19 ¹⁸	65	100	165	x	0
79	Ava-Campbell Hill, Jackson.....	19 ¹¹	70	370	440	25,000	0
80	Bartleso, Clinton.....	1	200	0	200	40,700 ±	0
81	Total Illinois ¹⁹		98,085	15,770	113,855	425,495,000 ²⁰	4,322,000 ²⁰

⁶ Total of lines 36, 47, 56, 57.

⁷ Abandoned 1930.

¹⁰ Abandoned 1925 ±.

¹¹ Abandoned 1934.

¹² Abandoned 1935.

¹³ Abandoned 1919.

¹⁴ Abandoned 1904.

¹⁵ Abandoned 1921.

¹⁶ Abandoned 1923.

¹⁷ Abandoned 1933.

¹⁸ Abandoned.

¹⁹ Total of lines 58 to 79 inclusive.

²⁰ The total oil production is the figure furnished by the U. S. Bureau of Mines and is not the exact total of the figures given in the table, which were obtained from other sources.

and Macoupin County fields and the new Bartelso field, had an increased production of approximately 30,000 bbl., or 31 per cent over 1935. The Bartelso field itself produced approximately 40,700 bbl. of oil. A decline in the production of the Carlyle field from 39,500 bbl. in 1935 to 28,200 in 1936 was owing to the fact that about 13 former producers were made input wells for water-flooding, and up to the end of 1936 no increased production from the adjacent wells had been effected by the water. Lack of sufficient gas reduced the amount of pumping in the whole field.

The well that discovered the new Bartelso oil field was located on the crest of a dome that was mapped, described, and recommended in *Bulletin* 20A of the Illinois State Geological Survey, published in 1912. Subsequent test wells on the west flank of the dome had obtained showings of oil but until 1936 there was no drilling on the high part of the structure.

The discovery well of the Bartelso oil field was the Bartelso Oil and Gas Company's C. Trame No. 1 well, SE. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 8, T.1N.,

TABLE 1.—(Continued)

Line Number	Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
	During 1936	Daily Average during Nov. 1936	To End of 1936	During 1935	During 1936	Maximum Daily during 1936	Completed to End of 1936	During 1936		At End of 1936				
								Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas ³	Producing Gas Only	Total Producing
57	220,000±	365±	x	y	y	y	411	4	11	y	319	y	0	319
58	4,137,600	10,557	x	y	y	y	19,005	26	258	48	13,553	y	1	13,554
59	153,000	430	0	0	0	0	463	9	0	69	196	0	0	196
60	0	0	x	0	0	0	68	0	0	0	0	0	0	0
61	0	0	x	x	x	x	53	0	y	y	0	0	y	y
62	0	0	x	0	0	0	8	0	0	0	0	0	0	0
63	0	0	14.4	0	0	0	7	0	y	0	0	0	0	0
64	4,758	0	0	0	0	0	22	0	0	12	0	0	0	0
65	0	0	135.8	0	0	0	4	0	0	0	0	0	0	0
66	0	0	1,050	0	0	0	18	0	0	0	0	0	0	0
67	0	0	x	0	0	0	17	0	0	0	0	0	0	0
68	0	0	0	0	0	0	5	0	0	0	0	0	0	0
69	0	0	117,447	13,420	37,047	y	17	1	0	0	0	0	10	10
70	0	0	990	0	0	0	4	0	0	0	0	0	0	0
71	28,200±	77±	0	0	0	0	164	0	0	21	88	0	0	88
72	0	0	0	0	0	0	12	0	0	0	0	0	0	0
73	30,160±	82±	0	0	0	0	122	0	0	y	45	0	0	45
74	y	y	0	0	0	0	22	0	0	y	3	0	0	3
75	23,200±	65±	0	0	0	0	103	0	4	y	46	0	0	46
76	53,100	138	0	0	0	0	237	7	0	0	45	0	0	45
77	0	0	0	0	0	0	23	0	0	0	0	0	0	0
78	0	0	x	0	0	0	20	0	0	0	0	0	0	0
79	0	0	x	0	0	0	35	0	0	0	0	0	0	0
80	40,700±	230±	0	0	0	0	9	9	0	0	9	0	0	9
81	4,445,000 ²⁰	12,100 ²⁰	x	y	y	y	20,433	52	262	150	13,985	y	11	13,996

Of the 30 wells drilling or temporarily shut down at the end of 1936, three are of special interest because of their location in the deep basin area. Two of these, the Pure Oil Company's Bradley No. 1, SW. $\frac{1}{4}$ SW. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 26, T.1N., R.7E., Wayne County, and Weiler No. 1, SE. $\frac{1}{4}$ SW. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 33, T.3N., R.8E., Clay County, were located on the basis of seismograph surveys. These had reached depths of approximately 2050 and 1425 ft., respectively, at the end of the year. The third, the T. E. Baldwin et al. H. Nichols' No. 1, SW. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 12, T.4N., R.4E., Marion County, is on the basis of a surface structure

TABLE 2.—*Summary of Drilling Operations in Illinois*

Wildcats Drilled in 1936										
	County	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Initial Production per Day	Remarks
		Sec.	Twp.	Rge.					Oil, U. S. Bbl.	
		Survey	Lat.	Long.						
1	Bond.....	31	6 N.	3 W.	1118	Pleistocene	Chester	F. S. Ray et al.		Dry
2	Brown.....	7	2 S.	3 W.	780	Pleistocene	Maquoketa	Super Oil Co.		Dry
3	Champaign.....	11	18 N.	9 E.	1725	Pleistocene	Trenton	Meyers et al.		Dry
4	Clinton.....	10	3 N.	2 W.	1283	Pleistocene	Chester	Hempen et al.		Dry
5	Clinton.....	5	1 N.	4 W.	1090	Pleistocene	Chester	Goldschmidt et al.		Dry
6	Clinton.....	25	2 N.	4 W.	1097	Pleistocene	Chester	J. Young et al.		Dry
7	Clinton.....	8	1 N.	3 W.	1118	Pleistocene	Chester	Ohio Oil Co.		Dry
8	Clinton.....	4	1 N.	3 W.	1090	Pleistocene	Chester	Meyers and Hawley		Dry
9	Clinton.....	7	1 N.	3 W.	1039	Pleistocene	Chester	Nollem Oil and Gas Co.		Dry
10	Clinton.....	7	1 N.	3 W.	1026	Pleistocene	Chester	Cooksey et al.		Dry
11	Clinton.....	4	1 N.	3 W.	1058	Pleistocene	Chester	Jonas et al.		Dry
12	Clinton.....	3	1 N.	3 W.	1089	Pleistocene	Chester	Hempen and Burgess		Dry
13	Clinton.....	8	1 N.	3 W.	1037	Pleistocene	Chester	Bartelo Oil and Gas Co.	115	Dry
14	Clinton.....	8	1 N.	3 W.	1030	Pleistocene	Chester	Nollem Oil and Gas Co.		Dry
15	Douglas.....	6	14 N.	7 E.	260	Pleistocene	Pennsylvanian	Meyers et al.		Dry
16	Jasper.....	15	8 N.	14 W.	721	Pleistocene	Pennsylvanian	National Cons. Oil Co.		Dry
17	Jasper.....	15	8 N.	14 W.	681	Pleistocene	Pennsylvanian	National Cons. Oil Co.	10	Dry
18	Lawrence.....	5	4 N.	11 W.	1460	Pleistocene	Ste. Genevieve	Yaw, Pierson, Sage		Dry
19	Logan.....	22	18 N.	2 W.	575	Pleistocene	Pennsylvanian	Ed. Hood et al.		Dry
20	Macoupin.....	15	8 N.	8 W.	465	Pleistocene	Pennsylvanian	Boone Oil Co.		Dry
21	Macoupin.....	36	11 N.	9 W.	1076	Pleistocene	Devonian	Hettick Oil Dev. Association		Dry
22	Marion.....	8	2 N.	4 E.	587	Pleistocene	Pennsylvanian	Iuka Oil and Gas Co.		Dry
23	Pike.....	19	5 S.	2 W.	412	Pleistocene	Devonian	Super Oil Co.		Dry
24	Pope.....	18	13 S.	6 E.	1000	Chester	Ste. Genevieve	Rodgers, Rumsey, Barger, et al.		Dry
25	Pope.....	5	11 S.	7 E.	455	Chester	Chester	O. B. Clark et al.		Dry
26	Randolph.....	31	4 S.	5 W.	904	Pleistocene	Chester	Cain and Beattie		Dry
27	St. Clair.....	2	2 N.	6 W.	1085	Pleistocene	Ste. Genevieve	Eisenmayer et al.		Dry
28	St. Clair.....	32	3 S.	6 W.	630	Pleistocene	Chester	W. O. Schook		Dry
29	St. Clair.....	2	2 N.	6 W.	1000	Pleistocene	Ste. Genevieve	Eisenmayer et al.		Dry
30	Vermilion.....	31	20 N.	12 W.	230	Pleistocene	Pennsylvanian	Central Assoc.		Dry
31	Washington.....	33	3 S.	4 W.	1100	Pleistocene	Ste. Genevieve	Hunlith et al.		Dry
32	Washington.....	34	1 S.	5 W.	1068	Pleistocene	Chester	J. E. Yock		Dry
33	Washington.....	10	1 S.	3 W.	1320	Pleistocene	Ste. Genevieve	Fricke et al.		Dry
Total.....									225	

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1936.....	3	8
Number of oil wells completed during 1936.....	47	2
Number of gas wells completed during 1936.....	3	0
Number of dry holes completed during 1936.....	9	31

(the Iola dome) described in a publication of the Illinois State Geological Survey¹. It had reached a depth of 760 ft. at the end of the year.

Of the 33 wildcat wells listed in Table 2, the great majority were not located in areas of known favorable structure.

It has long been recognized that there should be a systematic program of coring oil sands and making laboratory tests on the cores for the purpose of making reliable estimates of oil reserves in the producing fields of the state and to aid in applying improved methods of recovery. During previous years this program has been held back by lack of drilling but during 1936 for the first time substantial progress has been made. During 1936, cores of six sands have been taken in eight wells as follows: three from the Robinson sand (Pennsylvanian) in Crawford County; one from the Bridgeport sand (Pennsylvanian) in western Lawrence County; one from the Kirkwood (Cypress formation, Chester series) in eastern Lawrence County; one from the Hoing sand (Devonian) in the Plymouth

TABLE 3.—*Wells Drilled in Illinois in 1936*

County	Total Completions	Oil	Gas	Dry	Initial Production	
					Oil, Bbl.	Gas, M. Cu. Ft.
Bond.....	2	0	1	1		1.5
Brown.....	1	0	0	1		
Champaign.....	1	0	0	1		
Clark.....	9	6	1	2	16	"
Clinton.....	19	9	0	10	1016	
Crawford.....	11	9	0	2	49	
Douglas.....	1	0	0	1		
Jasper.....	2	1	0	1	10	
Lawrence.....	6	5	0	1	41	
Logan.....	1	0	0	1		
McDonough.....	13	9	0	4	38	
Macoupin.....	2	0	0	2		
Marion.....	1	0	0	1		
Pike.....	1	0	0	1		
Pope.....	2	0	0	2		
Randolph.....	1	0	0	1		
St. Clair.....	10	7	0	3	352	
Vermilion.....	1	0	0	1		
Wabash.....	5	3	1	1	233	1
Washington.....	3	0	0	3		
Total.....	92	49	3	40	1755	2.5

^a 100 lb. per sq. in. closed pressure.

¹ J. M. Weller and A. H. Bell: *Geology and Oil and Gas Possibilities of Parts of Marion and Clay Counties, Illinois, with Discussion of the Central Portion of the Illinois Basin*, Illinois State Geol. Survey R. I. 40 (1936).

field, McDonough County; one from the Carlyle sand (Cypress formation, Chester series) in the Bartelso field, Clinton County; and one from the Biehl sand (Pennsylvanian), Allendale field, Wabash County. The Illinois Geological Survey plans to publish the results of tests on the cores.

Three new repressuring plants, two using natural gas and one using air, were installed in Illinois oil fields in 1936. These were all in Crawford County and are using one, three, and six input wells, respectively. In the last-mentioned operation an increase in production has already been noted. In general other repressuring plants continued in operation with few changes in number of key wells (Table 1).

No new water-flooding projects were undertaken in Illinois fields in 1936. In some of the previous projects, as for example in the Carlyle field, Clinton County and Wamac field, Marion County, the number of input wells was increased. Neither of these fields had increased production in 1936.

Acid treatment of "lime pays" was used in 12 wells in Illinois fields in 1936. One of the wells treated was a new producer, so that no comparison is possible between oil production before and after treatment. The particular well referred to was a McClosky "sand" (Ste. Genevieve limestone) well in eastern Lawrence County. It had an initial production (after acid treatment) of 25 bbl. per day. Of the 11 old producing wells treated with acid, 6 had reported increases in production. Total daily production of the 6 wells before treatment was approximately 15 bbl. and after treatment approximately 170 bbl., an eleven-fold increase.

The fourth annual petroleum conference of Illinois-Indiana was held at Robinson, Ill., June 1, 1936 and was attended by about 150 oil operators, geologists, and geophysicists. The program was devoted to discussion of seismograph exploration, the geology and oil possibilities of the Illinois basin² and field problems in the recovery of oil.

The Fourth Annual Mineral Industries Conference of Illinois, held at Urbana April 24 and 25, included two half-day programs on oil and gas, one on Researches in Progress, the other on Needed Researches. Five of the ten papers presented have been published³.

² J. M. Weller: Geology and Oil Possibilities of the Illinois Basin. Illinois State Geol. Survey Ill. Pet. No. 27.

³ M. H. Flood: Problems in Oil Recovery. *Oil Weekly* (June 8, 1936) **81**, No. 13, 37-38.

W. S. Corwin: The Permeability of Oil Sands in Relation to Increased Recovery. *Oil Weekly* (June 15, 1936) **82**, No. 1, 58-62.

W. Bell: A Comprehensive Survey of Reserves and Underground Conditions in Illinois Oil Fields. *Oil Weekly* (Aug. 24, 1936) **82**, No. 11, 38-40.

A. H. Bell: Studies of Repressuring and Water-flooding. *Petr. Engr.*, **7**, No. 12, 60-62.

F. Squires: Present Status and Future Possibilities of Acid Treatment in Illinois Oil Fields. *Petr. Engr.*, **7**, No. 12, 40-42.

At a meeting of the Kansas Geological Society at Topeka, Kansas, Sept. 5, 1936, during the annual field conference, a paper was presented on Recent Oil Activity in the Illinois Basin⁴.

Data on the production of natural gas and natural gasoline in 1936 are not yet available. According to the U. S. Bureau of Mines (Mineral Market Reports No. M.M.S. 530, Feb. 12, 1937) the production of natural gas in Illinois in 1935 was 1448 million cubic feet (compared with 1838 million cubic feet in 1934). The average value in cents per thousand cubic feet at the wells in 1935 was 8.4¢ and the total value at the wells was \$122,000. Data concerning natural gasoline from 1931 to 1935 inclusive are given in Table 4.

TABLE 4.—*Natural Gasoline Produced in Illinois*

Year	Production, Thousands of Gallons	Value		Natural Gas Treated, Millions Cu. Ft.	Yield, Gal. per M. Cu. F.
		Total Thousands of Dollars	Unit Cents		
1931	5024	204	4.6	2106	2.39
1932	4558	139	3.2	1924	2.37
1933	3673	194	5.3	1701	2.14
1934	3810	183	4.8	1512	2.52
1935	2642	141	5.3	1076	2.64

PRODUCED BY COUNTIES IN 1935

Counties	Production, Thousands of Gallons	Total Value, Thousands of Dollars	Natural Gas Treated Millions Cu. Ft.	Yield, Gal. per M. Cu. Ft.
Clark and Cumberland.....	352	20	96	3.65
Crawford.....	1583	86	632	2.50
Lawrence and Wabash.....	707	34	348	2.03
State total.....	2642	140	1076	2.46

ACKNOWLEDGMENTS

Production data for oil and gas were furnished by the U. S. Bureau of Mines; the Illinois Pipe Line Co., Findlay, Ohio; the Ohio Oil Co., Marshall, Ill.; Petro Oil and Gas Co., St. Louis, Mo.; Bond County Gas Co., Greenville, Ill.; and Southwestern Oil and Gas Co., Sandoval, Ill. Mr. George V. Cohee, of the Survey Staff, assisted the writer in assembling the statistical data for this report.

⁴ A. H. Bell: Recent Oil Activity in the Illinois Basin. Abstract, Kansas Geol. Soc. (Sept. 1936).

Oil and Gas Developments in Indiana in 1936

BY RALPH E. ESAREY* AND M. M. FIDLAR†

(New York Meeting, February, 1937)

CONDITIONS in the oil and gas industry in Indiana were somewhat better in 1936 than in the previous year, owing in large part to increased

TABLE 1.—*Oil and Gas Production in Indiana*

Line Number	Field, County	Age, Years to End of 1936	Area Proved, Acres			
			Oil	Oil and Gas ^a	Gas	Total
1	Trenton, "Many".....	50	102,xxx	25,xxx	650,xxx	778,xxx
2	Greensburg, Decatur.....	43	0		19,xxx	19,xxx
3	Loogootee, Martin-Daviess.....	36	6xx		1,2xx	1,8xx
4	West Princeton, Gibson.....	33		860	5xx	860
5	Oakland City, Pike.....	29	2,000		y	2,xxx
6	Harrison County, Harrison.....	26	0	0	6,200	6,200
7	Shelburn-Graysville, Sullivan.....	25	4,1xx	3xx	1,8xx	6,2xx
8	Union-Bowman, Pike-Gibson.....	20	2,4xx	0	4xx	2,8xx
9	Alford, Pike.....	17	220	0	870	1,090
10	Oatesville-Wheeling, Pike-Gibson.....	17	1,6xx	0	0	1,6xx
11	Tri-County-Somerville, Pike-Gibson.....	11	160		80	240
12	Veale, Daviess.....	10	400			400
13	Siosi, Vigo-Sullivan.....	10	510			510
14	Rock Hill-Grandview, Spencer.....	8	160			160
15	Troy, Spencer.....	8	75	y	80	155
16	Francisco, Gibson.....	7		9xx		9xx
17	Hudsonville, Daviess.....	7	0	0	4xx	4xx
18	Bristow, Perry.....	7	120	0	55	175
19	Unionville, Monroe.....	7			2,200	2,200
20	Oaktown, Knox.....	6	40		760	800
21	Vanderburgh, Vanderburgh.....	5	250			250
22	Blairsville, Posey.....	2.7	600	0	0	600
23	Tell City, Perry.....	1.1	0	0	3xx	3xx

^a Footnotes for column heads and explanation of symbols are given on page 291.

Manuscript received at the office of the Institute Feb. 17, tables April 27, 1937.

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for new oil and gas structures. In addition, 15 wells were started in 1936 that were not completed by the end of the year.

The increase in gas production was due to the rapid development of the Oaktown field in Knox County. In 1935, the Alford field, in Pike County, was called upon to produce the bulk of the gas used in southwestern Indiana. The production of natural gas in 1936 in the Oaktown field far surpassed that of the Alford area, and accounts for the increase in total production. During the extremely cold early months of 1936, there was a greatly increased demand for gas in southwestern Indiana, and as a result water has begun to encroach upon many wells in the Oaktown field from which gas was taken in too great a quantity.

The increase in oil production for 1936 was due in part to increased drilling in proven areas, and to the reconditioning of wells on partly abandoned leases. Several wells that had dropped to the economic limit

TABLE 1.—(Continued)

Line Number	Number of Oil and/or Gas Wells					Depth, Average in Feet		Oil Production Methods at End of 1936	Pressure, Lb. per Sq. In. ^d		Character of Oil, Approx. Average during 1936						
	At End of 1936					Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells	Injection into Reservoir ^c	Average at End of	Gravity A.P.I. at 60° F.						
	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas ^b	Producing Gas Only	Total Producing						Maximum	Minimum	Weighted Average	Sulphur, Per Cent	Base ^e		
																Pumping	
1	y	2xx	y	5xx	7xx	1,050-1,250	980-1,230	2xx		325	y	y	38	24	36	y	P
2	0	0	0	23x	23x	907	886			300	120	115					
3	0	y	0	13		540	532	y		230	100	100					M
4	0	56	0	0	56	920	890	41	15	y	y	y	31	30	30.5	y	M
5	0	34	0	2	36	1,107-1,126	1,085-1,112	34		y	y	y	y	y	y	y	M
6	9	0	0	40	40	680	650	0		90	y	y	y	y	y	y	
7	y	32x	0	12	34x	325- 560 667- 775 810-2,285	298- 545 640- 730 800-2,270	30x	15	y	y	y	35	25	31.5	y	M
8	y	154	0	19	173	950 1,250 1,100 1,140	945 1,244 1,080 1,130	154		y	y	y	32	29	31	y	M,P
9		7	0	45	52	1,270-1,860 1,290-1,740	1,250-1,340 1,270-1,725	7		440	y	y	39	36	38	y	M
10	0	197	0	0	197	1,270-1,860 1,290-1,740	1,250-1,340 1,270-1,725	197		y	y	y			32		M
11	y	24	0	7	31	331 1,335	315 1,317	24		y	y	y	36	32	34	y	M
12	0	25	0	0	25	1,169	1,161	25					y	y	y	y	M
13	y	51	0	1	52	2,115 2,194	2,100 2,175	51							45.9	y	P
14	0	7	0	0	7	1,320	1,310	7							36	y	M
15	0	17	0	4	21	728 758 827	714 747 805	17							34.7	y	M,P
16	y	16	2	1	19	1,450 1,462	1,430 1,452	16		590	y	580	y	y	30	y	y
17	y	0	0	18	18	660	650	0		245	y	120					
18	y	30	0	5	35	350	330	30					y	y	34.7	y	A
19	17	0	0	0	0	850	800	0		250	y	y	y	y	32	0.1	M
20	y	5	0	38	43	610 802	580 790	5		325	y	y	y	y	32	0.1	M
21	0	60	0	0	60	911	899	60					28	24	26	y	A
22	0	18	0	0	18	1,031	1,007										
23	0	0	0	10	10	1,193 492	1,168 486	18 0		200	200	200	y	y	27	0.4	A

in production were put back into service after the price for crude oil increased in the last part of the year. Many of the wells in southwestern Indiana have never completely recovered from the proration imposed upon them a few years ago. Some activity resulted from the deep-drilling program in the entire coal basin of Illinois and Indiana.

In 1936, the Oaktown gas field was further developed, and drilling activity was heavy on a gas structure in Anderson township, Perry County, following the drilling of the discovery well late in 1935, and the laying of a pipe line into the area.

The outstanding new oil development of the year was the proving of the St. Johns structure in Armstrong and German townships, Vanderburgh County. The wells in this field seem to be holding up rather well at the end of the year.

TABLE 1.—(Continued)

Line Number	Character of Gas, Approx. Average during 1936		Producing Rock						Deepest Zone Tested to End of 1936	
	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Name	Age ¹	Character ²	Porosity ³	Net Thickness, Average in Feet	Structure ⁴	Number of Dry and/or Near-dry Holes to End of 1936	Depth of Hole, Ft.
1	950	y	Trenton	Ord	D, L	Por Fis	z	A	3,82x	Pre-Cambrian 3,996
2	847	y	Trenton	Ord	D, L	Por Fis	z	A	y	Pre-Cambrian 3,055
3	1,000	y	Chester	MisU	S	Por	15	A	33	St. Louis (Mis) 783
4			W. Princeton sand (Brazil ?)	PenL	S	Por	y	Af	26	St. Louis 2,048
5			Oakland City, Brown sand	MisU	S	Por	y	A	44	Paoli (Chester) 1,444
6	950		New Albany shale	DevU	H	Fis	85	M	39	Trenton 1,770
7	970		Unnamed (1, 2, 3, 4); Cypress; Niagara	Pen, Mis, Sil	S, S, L	Por	y	AM	66x	Niagara 2,328
8			Paoli, Cypress, Mooretown	MisU	S	Por	y	A	75	Salem (Mis) 2,205
9	y		Oakland City, Brown sand	MisU	S	Por	z	A	34	St. Louis 1,413
10			Sample, Paoli, Cypress, Mooretown	MisU	S	Por	y	A	49	Harrodsburg (Mis) 2,050
11	y	y	Brazil, Oakland City	PenL, MisU	S	Por	y	A	y	St. Louis 1,560
12			Veale sand	MisU	S	Por	y	A	54	Devonian (?) 2,618
13			Corniferous, Niagara	Dev, Sil	L	Por	y	D	10	Trenton 3,554
14			Bethel (Sample)	MisU	S	Por	y	MC	8	Mississippi Lime 1,500
15			Cypress, Mooretown	MisU	S	Por	y	N	22	Mississippi Lime 1,708
16	957		Brown sand	MisU	S	20	25	A	6	Ordovician 4,006
17	950	y	Barker sand	MisU	S	Por	10	T	y	St. Genevieve 1,021
18			Tar Springs, Cypress, Elwren	MisU	S	Por	20	ML	28	Mississippi Lime 710
19	980		Corniferous	Dev	D	Por	40	AF	4	Trenton 2,102
20	950	y	Staunton, Unnamed	PenL	S	Por	y	ML	27	Chester 1,593
21			Mansfield	PenL	S	Por	y	M	25	Glen Dean 1,795
22			Mansfield	PenL	S	25	30	ML	33	Chester 1,920
23	900		Jackson (Sample)	MisU	S	Por	y	MF	11	St. Louis 680

An interesting wildcat well was drilled in Johnson County, to a depth of 4092 ft. No production was obtained and the hole stopped in the rocks of the Lower Cambrian series.

Repressuring projects are now under way in two of the southwestern Indiana oil fields. The West Princeton pool, in Gibson County, is being repressured with compressed air, and natural gas is being used for this purpose in the Dodds Bridge field in Sullivan County. Because these projects were started late in the year, no definite results had been obtained at the end of 1936.

The treatment of wells with acid was continued through 1936. The oil wells producing from limestone appeared to respond favorably in most instances. A few gas wells drilled in the Trenton area during 1936 were treated with acid, to replace the customary shooting, but results were not satisfactory.

TABLE 2.—*Summary of Drilling Operations in Indiana*

Important Wildcats Drilled in 1936						
	County	Location			Total Depth, Ft.	Surface Formation
		Sec.	Twp.	Rge.		
		Survey	Lat.	Long.		
1	Johnson.....	4	12 N.	4 E.	4092	Dev
2	Knox.....	22	5 N.	10 W.	1516	Pen
3	Knox.....	23	5 N.	10 W.	575	Pen
4	Knox.....	Don. 119	4 N.	9 W.	725	Pen
5	Vanderburgh.....	11	6 S.	10 W.	1135	Pen
6	Sullivan.....	29	7 N.	8 W.	1067	Pen
7	Posey.....	14	6 S.	13 W.	1930	Pen
8	Dubois.....	25	1 N.	4 W.	850	Pen
9	Vanderburgh.....	26	5 S.	11 W.	1200	Pen
10	Vanderburgh.....	23	5 S.	11 W.	1200	Pen
11	Posey.....	34	6 S.	12 W.	1295	Pen
12	Perry.....	18	4 S.	1 W.	358	Mis
13	Pike.....	11	1 S.	7 W.	1135	Pen
14	Daviess.....	34	3 N.	5 W.	600	Pen
15	Knox.....	2	4 N.	9 W.	741	Pen
16	Perry.....	20	3 S.	2 W.	729	Mis
17	Pike.....	19	1 S.	8 W.	1057	Pen
18	Knox.....	26	5 N.	9 W.	782	Pen
19	Spencer.....	1	6 S.	4 W.	600	Pen
20	Daviess.....	3	2 N.	5 W.	570	Pen
21	Daviess.....	27	3 N.	5 W.	580	Pen
22	Daviess.....	13	2 N.	6 W.	790	Pen
23	Randolph.....	9	21 N.	15 E.	1200	Sil
24	Vanderburgh.....	31	5 S.	11 W.	1355	Pen

TABLE 2.—(Continued)

Important Wildcats Drilled in 1936

	Deepest Horizon Tested	Drilled by	Initial Production per Day		Remarks
			Oil, U. S. Bbl.	Gas, Millions Cu. Ft.	
1	L. Cambrian	J. L. Hassett et al.			Dry hole.
2	Chester	Becca Oil Trust			Good show oil.
3	Mansfield	Ky. Nat. Gas Corp.		1.47	
4	Mansfield	Joe Henley et al.			Dry hole.
5	Mansfield	Union Oil Co.			Dry hole.
6	Chester	Nelson Bros.			Dry hole.
7	Chester	J. C. Ellis			Dry hole.
8	Chester	Claude Noble			Dry hole.
9	Mansfield	P. E. Tichenor			Dry hole.
10	Mansfield	P. E. Tichenor			Dry hole.
11	Mansfield	L. R. Henley et al.		4.0	3000 M. cu. ft. gas at 370 ft.
12	Chester	Chas. Wyman	4		
13	M. Mis.	C. L. Trussler			Dry hole.
14	Chester	Oliphant & Sage		1.25	
15	Pottsville	H. C. Lord et al.			Dry hole.
16	M. Mis.	McGrain Oil & Gas Corp.			Show of oil at 575 ft.
17	Chester	Jas. Havens et al.			Dry hole.
18	Pottsville	H. C. Lord et al.			Dry hole.
19	Chester	T. F. Seitz			Dry hole.
20	Chester	Ky. Nat. Gas Corp.		0.22	
21	Chester	E. R. Parker		0.23	
22	Chester	Midwest Dev. Corp.			Dry hole.
23	Trenton	E. G. Henderson	2		
24	Mansfield	Karl Michel			Dry hole.
	Total.....		6	7.17	

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1936.....	10	5
Number of oil wells completed during 1936.....	41	4
Number of gas wells completed during 1936.....	43	10
Number of dry holes completed during 1936.....	54	42

Kansas Oil and Gas during 1936

BY W. A. VER WIEBE*

(New York Meeting, February, 1937)

It is becoming increasingly apparent that the State of Kansas contains one of the largest reserve areas for oil exploration in the United States. During the year 1936 no less than 54 new oil pools were discovered by drilling. In addition, seven gas pools were found, which may develop into oil pools when deeper horizons are tested. Several old pools increased their reserves when production was found in lower strata.

The data presented in Table 2 indicate that nearly 2000 wells were drilled in the state during 1936. Of these more than 1214 found commercial quantities of oil and at least 61 found marketable quantities of gas. The data are conservative because complete results on drilling are not available for the eastern part of the state. Ellis, Rice and Russell Counties share honors with a total of 10 new pools in each. Barton County is prominent with six pools; while those counties claiming fewer new pools are Clark, Ellsworth, Harvey, McPherson, Ness, Pawnee, Rooks, Stafford and Trego. Important additions to our gas reserves were found in Finney and Haskell Counties, which are north of the extensive Hugoton gas area and may some day be part of it.

At the close of the year there were 17,317 wells in the state rating as producers. By far the larger share (14,000) were classed as strippers and allowed to flow 100 per cent of their potential capacity, thus accounting for 33,500 bbl. a day. The remaining wells, capable of producing from 15 up to over 6000 bbl. per day, were limited in output according to these amounts. The largest wells having a potential of from 3000 to 7000 were allowed to flow from 2 to $3\frac{1}{2}$ per cent of their official potential capacity. The percentage rises until wells of 15 to 20-bbl. capacity have a rating of slightly over 83. On the basis of these calculations the total potential capacity of all wells was 1,667,814 bbl., and the daily amount allowed was 175,851. Nine of the pools most recently opened were still unable to market their oil and were classified as "shut-in" pools. Total production for the state for 1936 was somewhat over 58 million barrels.

STRIKING GEOLOGICAL DATA

Some interesting geological data were uncovered by deep drilling during the year. The most remarkable bit of information is the discovery

Manuscript received at the office of the Institute Feb. 13, 1937; tables April 9, 1937.

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that pre-Cambrian quartzite produces some of the oil and gas in the Orth pool in Rice County. A table of producing horizons and key horizons is presented in Fig. 1, so that the reader may compare this new and

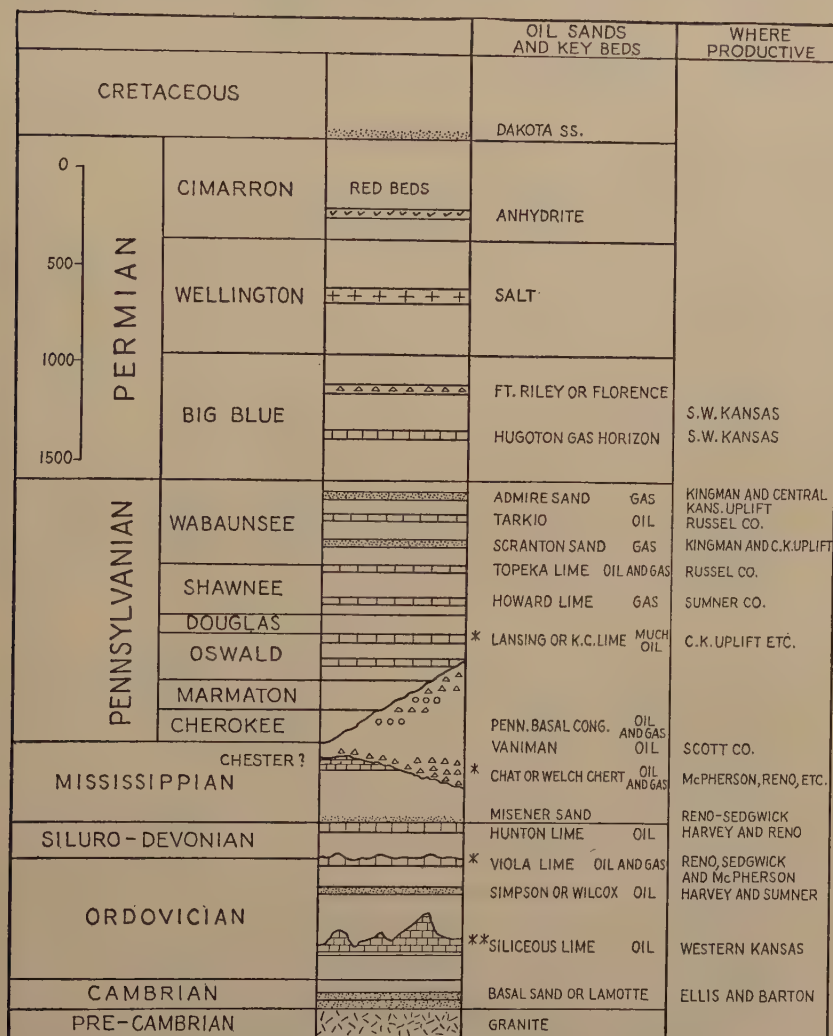


FIG. 1.—OIL-PRODUCING ZONES OF WESTERN KANSAS.

Drawn by Charles Matthews from data prepared by the author. Stars indicate most important producing horizons.

deepest producing horizon to those previously known. Among the producing levels listed in this skeleton columnar section are several that first came into production during the year 1936. Outstanding among them is the Tarkio lime, in the Wabaunsee formation, which now produces at East Gorham, Sullivan and Williamson. The highest producing formation is the Lecompton, which produces from one well in the Sullivan

TABLE 1.—Oil and Gas Production in Kansas

Line Number	Field, Survey, Township, Range	Age, to End of 1936		Area Proved, Acres			
				Oil	Oil and Gas ^a	Gas	Total
		Years	Months				
1	Barber County						
2	Aetna, 13-34-15.....	1	6			40	40
3	Medicine Lodge, 13-33-13.....	10	11			1,000	1,000
4	Whelan, 32-31-11 W.....	2	5	160			160
5	Barton County						
6	Ainsworth, 33-16-13.....		1	40			40
7	Albert, 36-18-16 W.....	2	11	160		80	160
8	Beaver, 16-16-12 W.....	2	1	160			160
9	Bloomer, 36-17-11.....	11	11	640			640
10	Davidson, 4-16-11 W.....	7	10	40			40
11	Eberhardt, 14-19-11 W.....	1	7	40			40
12	Ehly, 15-16-12.....	1	2	10			10
13	Ellinwood, 9-20-11 W.....	4	6	600			600
14	Feist, 29-18-11 W.....	1	3	10			10
15	Heizer, 16-19-14 W.....	1	5	10			10
16	Hiss, 31-20-13.....	1	8	40			40
17	Lanterman, 15-19-11 W.....	2	3	10			10
18	Peter, 24-20-11 W.....	1	3	600			600
19	Rick, 1-19-11.....	1	5	160			160
20	Silica, 31-19-10.....	4	11	3,200			3,200
21	Susank, 16-16-13.....		1	10			10
22	Butler County						
23	Anderson, 7-27-4 E.....	6	7	20			20
24	Augusta (North), 27-4E.....	22			1,280		1,280
25	Augusta (South), 28-4 E.....	20			7,660		7,660
26	Benton, 10-26-3 E.....	11		40			40
27	Brandt, 15-28-7 E.....	7	7	10			10
28	De Moss, 5-28-7 E.....	2	3	10			10
29	Douglass, 29-4 E.....	20		1,100			
30	Elbing, 8-23-4 E.....	18	5	1,880			1,880
31	Eldorado, 25-5 E. + 26-5 E.....	21			25,020		25,020
32	Fox Bush, 28-5 E.....	19		5,000			5,000
33	Garden-Shaffer, 26-6 E. + 27-6 E.....	10		1,600			1,600
34	Haverhill, 27-27-5 E.....	9	9	700	680		680
35	Hasett, 1-24-4 E.....	15		40			40
36	Keighley, 27-27-7 E.....	11		1,600			1,600
37	Kramer, 28-27-6 E.....	10		500			500
38	Leon, 19-27-6 E.....	10	3	500			500
39	McCullough, 1-28-6 E.....		11	160			160
40	Potwin, 36-24-3 E.....	15		2,500			2,500
41	Smook-Slusa, 19-26-6 E.....	18	10	1,500			1,500
42	Steinhoff, 21-29-6 E.....	10		40			40
43	Weaver, 1-28-5 E.....	7		160			160
44	Young, 27-26-7 E.....	17		400			
45	Chautauqua County						
46	Longton, 30 S. to 33 S. R. 12 E.....	34			200	7,000	7,000
47	Clark County						
48	Morrison, 21-32-21.....	8	2				
	17-32-21.....		3	160			160

^a Footnotes to column heads and explanation of symbols are given on page 291.

TABLE 1.—(Continued)

Line Number	Total Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells									
	To End of 1936	During 1935	During 1936	To End of 1936	During 1935	During 1936	Maximum Daily during 1936	Completed to End of 1936	During 1936		At End of 1936						
									Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas ^b	Producing Gas Only	Total Producing		
1	44,792	14,582	23,793	21,000				1									
2								10								1	1
3			23,793					2						2			2
4	44,792	14,582	1,163,590					1									
5																	
6																	
7	51,890	13,186	38,704					4							1	4	
8	137,179	113,000	124,179					9			9						
9	295,000		295,000					30			30			30			
10	4,679	2,000	2,679					1			1						
11	44,859	659	44,200					4			4						
12	744		744					1			1						
13	992,100	368,000	242,000					15			15			15			
14	18,200		18,200					1			1						
15	7,458	2,876	4,582					1			1						
16	29,000		29,000					3			3						
17	23,488	9,988	13,500					1			1						
18	144,211	9,711	134,500					13			13			13			
19	23,700		23,700					5			5						
20	4,889,967	822,000	3,684,300					175			175			175			
21								1			1						
22												2					
23																	
24	12,753,400	247,685	153,707					279	0	2		71	} 37				
25	32,192,838	475,377	424,968					735	1	17		189			22		
26			6,000					2				2					
27			2,730					1				1					
28			7,200					1				1					
29		43,000	39,600									28		28			
30	24,700,000 ¹	402,100	396,000					71				71		71			
31	159,056,003	3,906,330	3,492,325					3,031	0	31		1,839		15 1,854			
32	15,000,000	209,000	192,000									205		205			
33		300,000	252,000									65		65			
34	2,744,981	124,847	120,863	66	0	0						61		61			
35			2,400					2				2		2			
36		93,000										67		67			
37			189,000									33		33			
38	14,000,000		24,000									27		27			
39												3		3			
40		429,000	444,000									77		77			
41		77,500	68,400									41		41			
42			10,800									2		2			
43																	
44		48,000										20		20			
45		560,000															
46				35,000				130				6		10			
47																	
48								3				1		1			

¹ Includes Peabody.

TABLE 1.—(Continued)

Line Number	Depth, Average in Feet		Oil Production Methods at End of 1936	Pressure, Lb per Sq. In. ⁴		Character of Oil, Approx. Average during 1936		Character of Gas, Approx. Average during 1936		Producing Rock			
										Name			
	Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells		Initial	Average at End of		Gravity A.P.I. at 60° F.	Sulphur, Per Cent	Base ⁵	Btu. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	
			Flowing	Pumping		1935	1936						Weighted Average
1													
2	5,260	5,215											Viola
3	4,465	4,455			1,625								Chat
4	4,384	4,355	2				32						Chat
5													
6	3,395		1										Siliceous
7	3,616	3,601	4				35						Basal conglomerate
8	3,341	3,335	9				39						Basal conglomerate, Reagan
9	3,351	3,348											Siliceous
10	3,281	3,271	30				44						Siliceous
11	3,340	3,314	1				33						Siliceous
12	3,360	3,311	4				38						Siliceous
13	3,345	3,332	1										Basal conglomerate
14	3,334	3,304	15				41						Siliceous
15	3,430	3,433	1				40						Siliceous?
16	3,253	3,228	1				48						Oswald
17	3,285	3,270	3				36						Oswald
18	3,235	3,232	1				42						Siliceous
19	3,284	3,274	13				43						Siliceous
20	3,355	3,353	5				36						Siliceous
21	3,328	3,309	175				42						Siliceous
22	3,389		1										Siliceous
23		2,924	2				26						Viola
24	2,035	1,900	71				33	30	M	850			Kansas City, Wilcox, Siliceous
25	2,410	2,380											
26	2,460	2,410											
27	2,260	1,700											Lansing, Kans. City, Ft. Scott
28	2,520	2,445	189				40	40	M	850			Wilcox, Siliceous
29		2,765	2										Chat
30		2,700	1										Chat
31	1,830	1,790	28										Bartlesville
32	2,400	2,330	71				32	29	M				Lansing
33	2,200	600	1,839				35	18	M	675			Kansas City, Viola
34	2,680	1,700											
35	2,770	2,500	205										Admire Douglas etc.
36		2,730											Lansing, Kans. City, Ft. Scott
37													Viola, Simpson, Siliceous
38													Bartlesville
39													
40													
41	2,750	2,700	65										Bartlesville chat, Viola
42	2,490	2,470	61				39	20	P				Bartlesville
43	2,700	2,650	2										Chat
44	3,150		67										Bartlesville
45	2,710		33				36						Viola
46		2,660	27				38						Chat, Viola
47		3,050					38						
48			3										
49	2,255	2,250	77					14	P				Wilcox
50	2,725	2,660											Kansas City
51	2,735	2,700	41				39						Chat
52													Bartlesville
53													Viola
54													Chat
55													Bartlesville
56													Kansas City
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TABLE 1.—(Continued)

Line Number	Producing Rock					Number of Dry and/or Near-dry Holes to End of 1936	Deepest Zone Tested to End of 1936		Reference to Text ⁱ
	Age ^f	Character ^g	Porosity ^h	Net Thickness, Average in Feet	Structure ⁱ		Name	Depth of Hole, Ft.	
1									
2	Ord	L		45		1	Siliceous		
3	Mis	IR ²		10	D	6	Pre-Cam		
4	Mis	IR		29	A	1	Siliceous		
5									
6	Ord	D							
7	Pen	S		15	A	1	Pre-Cam		
8	Pen, Cam, Ord	SD		5	A	1	Pre-Cam		
9	Ord	D		10	A				
10	Ord	D		24	A	1			
11	Ord	D		49					
12	Pen	S		13					
13	Ord	D		30	Af	4			
14	Ord	D		3		3			
15	Pen	L		25	A		Pre-Cam		
16	Pen	L		15	A	1	Siliceous		
17	Ord	D		3					
18	Ord	D		10	A	2			O
19	Ord	D		2		1			
20	Ord	D		19	A	6			O
21	Ord	D							
22									
23									
24	Pen	L		45	A	40			A
	Ord	S		30					
	Ord	D	Por Cav	50					
25	Pen	L	Por	40	A	68	Pre-Cam		A
	Ord	L & D	Cav	35					
26	Ord	IR			MC		Ordovician		
27	Mis	IR			MC				
28	Mis	S			ML		Mis		
29	Pen	L			A		Siliceous		
30	Pen	L					Siliceous		
	Ord	L			D				
31	Pen	S	Por	15	A				
	Pen	L	Cav	25	A				
	Ord	L & D	Cav	60	Af	336	Pre-Cam	3,067	A
32	Pen	S			ML		Mis		
					ML				
33	Pen, Mis, Ord	S, IR, L			MC		Siliceous		
34	Pen	S		50	ML	10	Wilcox	3,177	A
35	Mis	IR		20	MC		Pre-Cam		
36	Pen	S			ML		Mis		
37	Ord	D			MC		Siliceous		
38	Mis, Ord	IR			A		Siliceous		
39	Ord	S			A				
40	Pen	L			MC		Siliceous		
	Mis	IR							
41	Pen	S			ML				
	Ord	L			MC				
42	Mis	L			MC				
43	Pen	S			ML		Mis		
44	Pen	L			D		Mis		
45	Mis	IR			A				
46									
47	Pen	L					Siliceous		O
48	Ord								

² Insoluble residue.

TABLE 1.—(Continued)

Line Number	Field, Survey, Township, Range	Age, to End of 1936		Area Proved, Acres			
				Oil	Oil and Gas ^a	Gas	Total
		Years	Months				
49	<i>Cowley County</i>						
50	Burden, 22-31-6 E.....	10		1,200			1,200
51	Carson, 19-32-3 E.....	12	7	400			400
52	Clark, 6-31-4 E.....	22		180			180
53	David, 35-30-4 E.....			500			500
54	Dexter-Otto, 33 + 34 S., R. 6 + 7E.....	33		1,000		1,000	1,000
55	Eastman, 31-30-6 E.....	12		700		700	700
56	Falls City, 17-35-7 E.....	20		400			400
57	Geuda Springs, 8-34-3 E.....		8	20			20
58	Graham, 12-33-3 E.....	12	7	400			400
59	Hittle, 21-31-4 E.....	10		300			300
60	Murphy, 8-35-3 E.....	3		120			120
61	Rainbow Bend, 20-33-3 E.....	13	1		2,000		2,000
62	Rock, 14-30-4 E.....	14	12	200			200
63	Sherwood, 11-31-4 E.....		8	40			40
64	Smith, 10-31-3 E.....	19		200			200
65	State, 15-32-4 E.....	10		1,500			1,500
66	Trees, 19-30-4 E.....	2		160			160
67	Wethered, 28-31-3 E.....	1	6	160			160
68	Winfield, T. 32 S., R. 4 + 5 E.....	22	2		6,000		
69	Miscellaneous.....			500			
70	<i>Edwards County</i>						
71	McCarty, 30-25-17.....	7	8		80		80
72	<i>Elk County</i>						
73	Denton, T. 29 + 30 R. 9 E.....	25			3,600		3,600
74	Ferguson, 6-31-8 E.....	8	6		400		400
75	Hanna 12-29-8 E.....			600			600
76	Moline, 3-31-10 E.....	9	1		600		
77	Webb, 28-31-10 E.....	12	3		3,600		3,600
78	Miscellaneous.....			1,000			1,000
79	<i>Ellis County</i>						
80	Antonino, 26-14-19.....		7	20			20
81	Bemis, 16-11-17.....	1	3	360			360
82	Catherine, 3-13-17.....		7	30			30
83	Hadley, 20-11-17.....	7	5	10			10
84	Haller, 10-11-18.....		6	10			10
85	Kraus, 22-14-19.....		6	10			10
86	Madden, 26-15-18.....		7	10			10
87	Marshall, 36-11-18.....		2	10			10
88	Penney Wahn, 13-15-20.....		4	10			10

TABLE 1.—(Continued)

Line Number	Total Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells								
	To End of 1936	During 1935	During 1936	To End of 1936	During 1935	During 1936	Maximum Daily during 1936	Completed to End of 1936	During 1936		At End of 1936					
									Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas ^b	Producing Gas Only	Total Producing	
49																
50			186,000									36				36
51	2,790,000	97,000	87,600									30				30
52	772,000		9,600									3				3
53			101,000									13				13
54								22				0			4	4
55	1,900,000	97,000	86,400					69				53	19			34
56	780,000			15,000				26				0		0		0
57												2				2
58	2,359,000	50,000	43,960					30				13				13
59			26,154									14				14
60			65,719													6
61	12,125,000	425,000	350,712					137				55				55
62	1,175,000	25,000	23,904					22				18				18
63			10,882									2				2
64		23,000	19,429					13				11				11
65			31,508					41				11				11
66			89,790									9				9
67			147,777									8				8
68	9,960,000	438,000	346,580	420				214				130		30		160
69	3,200,000		95,736									49				49
70																
71	86,690	3,185	2,306					5				1				1
72		581,000		7,665		468										
73								110				35		20		55
74			72,720					12				11				11
75								34								19
76								75					66			66
77								147					61			
78																
79	1,831,219	169,000	717,476													
80	4,862		4,862					2								1
81	256,650	1,125	255,525					25								25
82			10,400					3				3				3
83	75,000	41,208						1				1				1
84	6,734		6,734					1				1				1
85	6,430		6,430					1				1				1
86	5,490		5,490					1				1				1
87								1				1				1
88								1				1				1

TABLE 1.—(Continued)

Line Number	Depth, Average in Feet		Oil Production Methods at End of 1936		Pressure, Pounds per Square Inch ^a		Character of Oil, Approx. Average during 1936			Character of Gas, Approx. Average during 1936			Producing Rock	
	Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells		Initial	Average at End of		Gravity A.P.I. at 60° F.			B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Name	
			Flowing	Pumping		1935	1936	Weighted Average	Sulphur, Per Cent	Base ^c				
49														
50				36									Peru (1 well)	
51		2,600		30				38					Bartlesville	
52		3,450						40					Layton	
53		2,840		3				38					Siliceous	
54		325		13									Bartlesville	
55	2,870	1,100		0	250								Bartlesville	
56		2,770						34	17				Admire ³	
57		2,000		0				41					Shawnee	
58		3,320		2									Bartlesville	
59		2,550		13				38					Stalnaker ⁴	
60		3,500						40					Chat	
61		2,400		14									Layton	
62	3,250	3,200		6									Siliceous	
63	2,805	2,760		55				40			15		Stalnaker	
64				18				38					Chat	
65		3,050		2									Burgess	
66		2,300		11				38					Bartlesville	
67		3,500		11									Bartlesville	
68				9									Bartlesville	
69		3,400		8				35					Siliceous	
70		600		130				37					Admire gas ⁵	
71		1,400+						34					Stalnaker, Cherokee, Siliceous	
72	4,545	4,535		49										
73				1	1,300			35					Basal congl.	
74		1,450		35									{ Encill	
75	2,021	1,865		11				36					{ Mis lime	
76		2,000											{ Siliceous	
77													{ Encill, Layton	
78													{ Siliceous	
79		1,150		66				36					Layton	
80	3,710	1,980											Encill	
81	3,040	1,100		61				37					Mis Lime	
82	3,382	1,350											{ Encill	
83	3,362	1,650											{ Red	
84	3,440	2,286											{ Ft. Scott	
85	3,045	1,500						36					{ Siliceous	
86		2,000						34					Encill	
87													Mis Lime	
88	3,710	3,703		1				32					Basal congl.	
89	3,040	3,032		25				29					Topeka	
90	3,382	3,380						35					Siliceous	
91	3,362	3,274		3				30					Oswald	
92	3,440	3,428		1				29					Basal congl.	
93	3,045	3,036		1				40					Topeka	
94	3,740	3,737		1				35					Basal congl.	
95	3,341	3,331		1				37					Oswald	
96		3,600											Siliceous	
97		3,650		1									Siliceous	
98	3,658	3,653		1				31					Basal congl.	

^a Helium gas in Admire.^b Helium gas at 1475 ft.^c Also Peacock at 1400 and Layton 2300 ft.

TABLE 1.—(Continued)

Line Number	Producing Rock					Deepest Zone Tested to End of 1936		Reference to Text ⁱ
	Age ^f	Character ^g	Porosity ^h	Net Thickness, Average in Feet	Structure ⁱ	Number of Dry and/or Near-dry Holes to End of 1936	Name	Depth of Hole, Ft.
49								
50	Pen	S			ML		Siliceous	
51	Pen	S			D		Siliceous	
52	Ord	D						
53	Pen	S			ML		Ordovician	
54	Pen	S			ML		Mis	
55	Pen	S			A		Pre-Cam	
56	Pen	S						
57	Pen	S			ML		Ordovician	3,399
58	Mis	S			N		Ordovician	3,212
59	Ord	IR					Mis	
60	Pen	S			D			
61	Mis	D			MC		Siliceous	
62	Pen	IR						
63	Pen	S			MC		Siliceous	3,500
64	Pen	S			ML		Ordovician	3,300
65	Pen	S						
66	Ord	S			N		Ordovician	3,450
67	Pen	D			D		Siliceous	
68	Pen	D			ML		Mis	
69	Pen & Ord	D			D			
70		S			D		Reagan	4,140
71	Pen	S & D			A			
72								
73	Pen	DR ¹¹		10			Siliceous	
74	Pen	S			D		Siliceous	2,641
75	Pen	L						
76	Pen	S			AM		Siliceous	2,912
77	Pen	S					Siliceous	
78	Pen	S		40	N			
79	Ord	L						
80	Pen	S			D		Siliceous	2,286
81	Ord	L						
82	Pen	DR						
83	Pen	L						
84	Pen	DR						
85	Pen	L						
86	Pen	D		10			Siliceous	
87	Ord	L						
88	Pen	D		5				

¹¹ Detrital rubble.

TABLE 1.—(Continued)

Line Number	Field, Survey, Township, Range	Age, to End of 1936		Area Proved, Acres			
				Oil	Oil and Gas ^a	Gas	Total
		Years	Months				
89	Ruder, 17-15-18.....	1	5	500			500
90	Shutta, 32-11-17.....	8	2	160			160
91	Solomon, 28-11-19.....		7	10			10
92	Uberty, 12-13-18.....		2	10			10
93	Victoria, 3-14-17.....	1	1	20			20
94	Walters, 2-12-18.....		8	10			10
95	Yocemento ⁶ , 9-13-19.....	7	7	40			40
96	<i>Ellsworth County</i>						
97	Breford ⁷ , 7-17-10.....	4	4	250			250
98	Heiken ⁸ , 26-17-10.....	6	3	80			80
99	Lorraine ⁹ , 14-17-9.....	2	2	1,800			1,800
100	Stoltenberg, 21-16-10.....	5	7	300			300
101	Stratman ¹⁰ , 12-17-10.....	5	10	200			200
102	<i>Greenwood County</i>						
103	Atyco-Pixlee, 25-21-10 E.....	13		1,000			1,000
104	Browning, 8-22-10 E.....	12		3,800			3,800
105	Burkett, 13-23-10 E.....	12		2,700			2,700
106	Climax, 7-27-11 E.....	10		100			100
107	De Malorie-Souder, 19-21-10 E. 6-22-10 E.....	12		4,500			4,500
108	Eureka, 35-25-10 E.....	16		1,200			1,200
109	Fankhouser, 32-21-12 E. 10-22-12 E.....	10		2,500			2,500
110	Hamilton, 26-23-11 E. 6-24-12 E.....	7		3,000			3,000
111	Lamont, 15-22-12 E. 28-22-13 E.....	9		2,600			2,600
112	Madison, 1-15 T. 22 R. 11 E.....	15		3,000			3,000
113	Quincy, 25-24-12 E. 18-25-14 E.....	10		3,600			3,600
114	Reece, 21-26-9 E.....			1,200			1,200
115	Sallyards, 17-25-9 E. 26-26-8 E.....	15		8,000			8,000
116	Scott, 19-23-9 E. 26-23-8 E.....	11		2,500			2,500
117	Seeley, 22-22-11 E. 27-23-11 E.....	14		7,000			7,000
118	Sewery, 16-28-11 E.....			200			200
119	Teeter, 36-22-9 E. 28-23-9 E.....	14		2,700			2,700
120	Thrall, 28-23-10 E. 9-25-9 E.....			7,000			7,000
121	Virgil, 24-22-13 E. 26-24-12 E.....	20		18,000			18,000
122	Wiggins, 7-24-11 E. 36-24-10 E.....	11		2,500			2,500
123	Wilkinson, 11-25-8 E.....			1,300			1,300
124	Miscellaneous.....			1,000			1,000
125	<i>Harvey County</i>						
126	Halstead ¹¹ , 36-22-2. 11-23-2.....	8	5		1,500		1,500
127	Hesston, 8-22-1.....	2	5	40			40
128	Hollow-Nikkel, 33-21-3. 19-22-3.....	5	1				
129	Schowalter, 6-22-1.....	1	9	40			
130	Sperling, 23-22-2.....	1	11				
131	Walton, 4-23-2E.....	18	1	80			
132	<i>Kingman County</i>						
133	Cunningham, 30-27-10.....	5	11	800			800
134	<i>McPherson County</i>						
135	Canton (North), 26-18-1.....	6	10				10

⁶ Abandoned 1935.⁷ Includes Breford south.⁸ Includes Becker.⁹ Includes South Lorraine¹⁰ Includes Wilkins.¹¹ Includes Warkentine and Herzler

TABLE 1.—(Continued)

Line Number	Total Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
	To End of 1936	During 1935	During 1936	To End of 1936	During 1935	During 1936	Maximum Daily during 1936	Completed to End of 1936	During 1936		At End of 1936				
									Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas ^a	Producing Gas Only	Total Producing
89	213,896	3,650	210,246					16				16			16
90	1,192,861		186,180					12				12			12
91								1				1			1
92								1				1			1
93	13,906	306	13,600					2				2			2
94	18,000		18,000					1				1			1
95	60,891							4				1			1
96	8,500,000														
97	516,377	137,000	128,284					9				9			9
98	259,313	97,000	41,384					7				5			5
99	4,130,000	1,700,000	2,430,105					92				92			92
100	1,845,749	467,000	213,579												
101	1,700,647	191,000	158,024					21				19			19
102	100,250,000	4,000,000	3,700,000												
103		119,000	110,727									70			70
104		235,000	257,020									125			125
105		91,000	83,632									97			97
106			6,204									2			2
107		200,000	186,100									151			151
108			20,200									13			13
109		59,000	53,100									74			74
110		183,000	162,650									94			94
111		162,000	170,400									103			103
112	5,000,000	302,000	284,650									111			111
113		120,000	307,530									70			70
114		52,000	45,450									15			15
115		288,000	278,000									229			229
116		100,000	91,390									62			62
117		450,000	396,000									332			332
118			5,400									9			9
119		310,000	264,000									212			212
120		266,000	228,000									294			294
121	25,000,000	625,000	576,000									468			468
122		70,000	60,000									54			54
123		48,000	42,000									34			34
124			22,470									33			33
125			1,499,393												
126	316,000	20,946	81,750									13		4	17
127	12,000	6,363	1,075					2				1			1
128	15,116,600	2,833,626	1,354,600					140			40	131			131
129	59,968	19,523	40,445									4			4
130	62,685	41,183	21,502									2		7	9
131	123,000	750						7				7			7
132															
133	1,214,831	295,877	211,527									36		3	39
134	50,500,000		4,383,519					15				15			15
135	9,784		9,784					1				1			1

TABLE 1.—(Continued)

Line Number	Depth, Average in Feet		Oil Production Methods at End of 1936	Pressure, Pounds per Square Inch ^a		Character of Oil, Approx. Average during 1936			Character of Gas, Approx. Average during 1936			Producing Rock	
	Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells		Initial	Average at End of		Gravity A.P.I. at 60° F.	Sulphur, Per Cent	Base ^c	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Name
			Flowing	Pumping		1935	1936	Weighted Average					
89	3,440	3,432		16			34						Oswald ¹²
	3,582	3,572					36						Siliceous
90	3,284	3,280		12			35						Oswald
	3,575	3,569					29						Siliceous ¹³
91	3,632	3,629		1			21						Siliceous
92	3,707			1									Siliceous
93	3,303	3,298		2			36						Oswald
	3,560	3,512					33						Siliceous
94	3,165	3,160		1			35						Topeka
95	3,597	3,592		1			32						Oswald
96													
97	3,152	3,140		9			45						Oswald
98	3,407	3,385		5			44						Siliceous
	3,243	3,222											Siliceous
99	3,060	3,200		92			46						Oswald ¹⁴
	3,205												Siliceous
100	3,347	3,333					44						Siliceous
101	3,271	3,255		19			43						Siliceous
102													
103		2,327		70			41						Bartlesville
104	2,390	2,314		125			41						Bartlesville
105	2,100	2,000		97			41						Bartlesville
106		1,900		2			32						Mis Lime
107		2,150		151			41						Bartlesville
108		2,000		13									Mis Lime
109		1,750		74			41						Bartlesville
110	1,837	1,765		94			41						Bartlesville
111		1,650		103			41						Bartlesville
112		1,800		111			41						Bartlesville
113		1,420		70			38						Bartlesville
114				15									Mis Lime
115	2,500	2,350		229				24	M				Bartlesville
116	2,600	2,525		62									Bartlesville
117	1,975	1,930		332			42						Bartlesville
118				9									Mis Lime
119	2,550	2,400		212			41	19	M				Bartlesville
120	2,350	2,190		294									Bartlesville
121		1,550		468			41						Bartlesville
		1,700											Mis Lime
122	1,875	1,860		54			40						Bartlesville
123		2,500		34			41						Bartlesville
124				33									Mis lime
													Viola
125													
126	3,005	2,961		13			35						Chat
127	3,317	3,310		1			40						Hunton
128	3,208	3,195		131			43						{ Chat
	3,509	3,507											{ Hunton
													{ Wilcox
													{ Siliceous
129	3,320	3,298		4			35						Hunton
130	3,142	2,955		2			35						Chat
	3,345	3,279											Hunton
131		2,440					35						Kansas City
132													
	3,464	3,390											{ Oswald
133	4,012	3,923			1,375								{ Viola
	4,175	4,093	36				36						{ Siliceous
134													
135	2,832	2,803		1									Chat

¹² Two "pays" in Oswald.¹³ First commercial siliceous in western Kansas.¹⁴ Gas in Wabaunsee at 2200 ft.

TABLE 1.—(Continued)

Line Number	Producing Rock					Number of Dry and/or Near-dry Holes to End of 1936	Deepest Zone Tested to End of 1936		Reference to Text ¹
	Age ^f	Character ^g	Porosity ^h	Net Thickness, Average in Feet	Structure ⁱ		Name	Depth of Hole, Ft.	
89	Pen	L		8	D	2	Siliceous	3,582	O
90	Ord	D		10					
90	Pen	L		4	A	5	Siliceous	3,575	
91	Ord	D		6					
92	Ord	D		3					
93	Pen	D							
93	Ord	L		5		1			
94	Ord	D		10					
94	Pen	L		5					
95	Pen	L		5	A	2	Pre-Cam		
96									
97	Pen	L		12	A	4	Pre-Cam		
98	Ord	D		22	A				
98	Ord	D		21	A	5			
99	Pen	L							
	Ord	D			A	3			
100	Ord	D		14	A	5	Pre-Cam		
101	Ord	D		16	A	7			
102									
103	Pen	S			ML				
104	Pen	S			ML				
105	Pen	S			ML				
106	Mis	L			MC				
107	Pen	S			ML				
108	Mis	L			MC				
109	Pen	S		70	ML				
110	Pen	S			ML				
111	Pen	S			ML				
112	Pen	S			ML				
113	Pen	S			ML				
114	Mis	L _s			MC				
115	Pen	S			ML				
116	Pen	S			ML				
117	Pen	S			ML				
118	Mis	L			MC				
119	Pen	S			ML				
120	Pen	S			ML				
121	Pen	S			ML				
	Mis	L			MC				
122	Pen	S			ML				
123	Pen	S			ML				
124	Mis	L			MC				
	Ord	D							
125									
126	Mis	IR		44	A	5	Siliceous	3,554	O
127	S-D	L		7	A				
128	{ Mis S-D Ord Ord	{ L S D D							
					Af	14			
129				22	A		Siliceous		
130				87	A	1	Siliceous		
	S-D	L							
131	Mis	IR							
	S-D	L							
132	Pen	L		74		8			
133	Pen	L			Af	2	Siliceous	4,195	
	Ord	L							
	Ord	D							
134									
135	Mis	IR		29	A	1	Siliceous		

TABLE 1.—(Continued)

Line Number	Field, Survey, Township, Range	Age, to End of 1936		Area Proved, Acres			
				Oil	Oil and Gas ^a	Gas	Total
		Years	Months				
136	Chindberg, 18-19-2. 13-19-3.....	7	4		700		700
137	Galva (gas), 10-19-2.....	7	6			1,500	1,500
138	Graber, 29-21-1.....	2	5	1,200			1,200
139	Johnson, 35-19-3. 11-20-3.....	4	11		700		700
140	McPherson, 32-18-2.....	10	4		2,000		2,000
141	Ritz Canton, T. 19 + 20 R. 1 + 2.....	7	11		13,000		13,000
142	Voshell, T. 20 + 21 R. 3.....	7	9		3,500		3,500
143	<i>Marion County</i>						
144	Covert-Sellers, W. 1/2 of 21-4.....	16	10	2,400			2,400
145	Florence-Urshell, 20-21-5.....	17	1	3,000			3,000
146	Hillsboro, 7-19-3 E.....	9	3	360			360
147	Lost Springs, 22-17-4.....	10	4	2,400			2,400
148	Peabody, 5-22-4.....	17	4	3,000			3,000
149	Propp, 8-19-4 E.....	10	9				
150	<i>Ness County</i>						
151	Aldrich, 7-18-25.....	7	3	40			40
152	Thompson, 13-18-26.....		7	40			40
153	<i>Pawnee County</i>						
154	Pawnee Rock, 13-20-16.....		4	40			40
155	<i>Reno County</i>						
156	Abbyville, 24-24-8.....	9	11	80			80
157	Burton, T. 23 + 24 R. 4 W.....	6	4		5,000		5,000
158	Haury, 1-23-4.....	6	4		120		120
159	Haven, 30-24-4.....	1	4	40			40
160	Hilger, 16-26-4.....	2	10	600			600
161	Lerado, 10-26-9.....	1	1	600			600
162	Yoder, 34-24-5.....	1	2	80			80
163	<i>Rice County</i>						
164	Bowman, 22-19-10.....		5	10			10
165	Brandenstein, 10-19-10.....	3	2	40			40
166	Chase ²⁰ , 19-9. 20-10.....	5	10	4,000			4,000
167	Doran, 13-19-10.....		3	10			10
168	Edwards, 3-18-8.....		11	300			300
169	Empire, 8-20-9.....		6	40			40
170	Galt, 8-18-7.....	1	3	10			10
171	Geneseo, 25-18-8.....	2	8	600			600
172	Guldner, 16-18-9.....	1	6	160			160
173	Haferman, 6-19-9.....		7	160			160
174	Hauschild ²¹ , 15-21-7.....		9	600			600
175	Keesling, 15-20-9.....	1	9	600			600
176	Lyons (Pulliam), 35-19-8.....		5			40	40
177	Mantel, 18-20-10.....		2	10			10
178	Orth, 27-18-10.....	5	6		600		600
179	Ploog, 33-18-9.....	6	7	200			200
180	Ponce, 28-21-7.....		6	10			10
181	Raymond, 21-20-10.....	7	7	1,000			1,000
182	Rickard, 22-18-9.....	1	3	10			10
183	Saxman, 5-21-7.....		4	40			40
184	Schartz, 33-19-10.....		6	160			160
185	Stumps, 5-18-10.....	1	8	160			160

²⁰ Includes Beyer Grove Sharpe and Volkland.²¹ Includes Alberta Johnson and Theede.

TABLE 1.—(Continued)

Line Number	Total Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
	To End of 1936	During 1935	During 1936	To End of 1936	During 1935	During 1936	Maximum Daily during 1936	Completed to End of 1936	During 1936		At End of 1936				
									Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas ^b	Producing Gas Only	Total Producing
136	687,349	307	187,280									19		10	29
137				9,672										48	48
138	639,061	166,214	434,025					45				45			45
139	1,741,995	313,369	174,000	250								17		8	25
140	573,200	147,522	160,700									34		18	52
141	26,869,000	3,100,000	2,317,100	44,000									257	98	355
142	19,400,000	1,700,000	1,100,633	4,300	2,350							120			120
143			269,378												
144	11,100,000 ¹⁸	84,000	67,200									21			21
145		77,500	68,400									18			18
146	1,481,500	131,174	120,900									14			14
147		142,000	12,900									37			37
148		80,500													
149				319										3	
150															
151	14,791	2,392	3,933									1			1
152	3,137		3,137									1			1
153															
154												1			1
155	16,900,000		6,043,935												
156	233,749	75,000	51,135									4			4
157	13,100,000 ¹⁷	7,338,850 ¹⁷	2,685,105	18,000	7,860								192	36	228
158			2,458,552									111			111
159	37,869	8,127	164,577	1,700	287								16		16
160	414,563	66,174	29,742									3			3
161	343,373	9,186	301,341									22			22
162	22,153	2,867	334,187									13			13
163	29,620,000		19,296									4			4
164			11,216,771									1			1
165	279,006	97,000	42,395									2			2
166	12,108,744	5,044,759	3,470,100									211			211
167	7,418		7,418									1			1
168	180,570		180,570									18			18
169	29,850		29,850									4			4
170	10,887	1,132	9,755									1			1
171	720,846	266,000	397,000									24			24
172	144,688	35,588	109,100									7			7
173	54,800		54,800									6			6
174	395,100		395,100									22			22
175	1,109,170	235,000	874,170									39			39
176							75							1	1
177															
178	341,864	81,000	84,100					13				8		1	8
179	801,339	220,000	204,315									10			10
180	2,631		2,631									1			1
181	4,140,000	1,037,000	1,111,500										56		56
182	16,736	4,014	12,722									1			1
183	12,568		12,568									2			2
184	72,146		72,146									13			13
185			160,860									10			10

¹⁸ Includes Florence-Urshell.¹⁷ Includes Haury and Stone.

TABLE 1.—(Continued)

Line Number	Depth, Average in Feet		Oil Production Methods at End of 1936		Pressure, Pounds per Square Inch ^d		Character of Oil, Approx. Average during 1936			Character of Gas, Approx. Average during 1936		Producing Rock	
												Name	
	Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells		Initial	Average at End of		Gravity A.P.I. at 60° F.	Sulphur, Per Cent	Base	B.t.u. per Cu. Ft.		Gal. Gasoline per M. Cu. Ft.
			Flowing	Pumping		1935	1936						
136	3,009	2,363		19				37					Lansing
		2,996											Chat
137	2,964	2,900			1,025								Chat
138	3,298	3,274		45				41					Hunton
139	3,046	2,984		17	990			37					Chat
140	2,395	2,340		34	975		500	35					Lansing
	2,978	2,927						37					Chat
	3,200	3,190						40					Viola
141	2,399	2,360		257	900		500	32	50				Lansing
	2,983	2,972						37	19				Chat
	3,414	3,412											Viola
	3,444	3,440											Wilcox
142	3,108	3,055			1,000		365	36					Chat
	3,304	3,301						42					Viola
143	3,325	3,322						41					Wilcox
	3,483	3,394											Siliceous
144	2,435	2,330						32					Viola
145	2,340	2,300						34					Viola
146		2,800						37					Viola
147		2,365						37					Chat
148		2,532											Viola
149		2,370			845								Chat
150													
151	4,430	4,428						33					Siliceous
152	4,492	4,446						36					Chat
153													
154	3,841	3,815						36					Siliceous
155													
156	3,544	3,540						37					Oswald ¹⁸
								37			0.6		Chat
157	3,591	3,585			1,200		750	42					Hunton ¹⁹
158					1,200		1,045	39					Chat
159	3,399	3,350						38					Chat
160	4,067	4,062						40					Viola
161	4,156	4,137						40					Viola
162	3,501	3,402						36					Chat
163													
164	3,297	3,286											Siliceous
165	3,026	3,014						44					Oswald
166	3,284	3,246						45					Siliceous
167	3,311	3,291											Siliceous
168	3,282	3,278						41					Siliceous
169	3,291	3,272						43					Siliceous
170	3,230	3,205						41					Siliceous
171	3,175	3,132						39					Siliceous
172	3,230	3,227						45					Siliceous ²³
173	3,216	3,192						48					Siliceous
174	3,393	3,363						36					Basal congl.
175	3,265	3,239	22	39				42					Siliceous
176	3,385	3,270											Siliceous
177				1									Siliceous
178	3,243	3,240		9				45					Quartzite
	2,936	2,906											Oswald
179	3,271	3,252		10				47					Siliceous
180	3,431	3,388		1				36					Chat
181	3,140	3,130		56				41					Oswald
	3,351	3,330						43					Siliceous ²⁴
182	3,305	3,285		1				47					Wilcox
183	3,337	3,331	2					38					Basal congl.
184	3,318	3,310		13									Siliceous
185	3,267	3,229		10				43					Siliceous

¹⁸ Gas in Wabaunsee at 2075.¹⁹ Some oil in Siliceous at 3775.²³ Gas in Oswald at 2884.²⁴ Gas in Wabaunsee

TABLE 1.—(Continued)

Line Number	Producing Rock					Deepest Zone Tested to End of 1936		Reference to Text ¹
	Age ²	Character ³	Porosity ⁴	Net Thickness, Average in Feet	Structure ⁵	Number of Dry and/or Near-dry Holes to End of 1936	Name	Depth of Hole, Ft.
136	Pen	L		13	A	4	Siliceous	
137	Mis	IR		64	D		Siliceous	
138	S-D	L		24	A		Siliceous	
139	Mis	IR		62	Af	6	Siliceous	
140	Pen	L						
	Mis	L			D	11	Siliceous	
141	Ord	L			D	42	Siliceous	
	Pen	IR			MC			
	Mis	L						
	Ord	S						
142	Ord	IR		53	Af	13		
	Mis	L		3				
143	Ord	S		3				
	Ord	D						
144	Ord	L			D		Pre-Cam	
145	Ord	L			D			
146	Ord	L			D		Siliceous	
147	Mis	IR			MC		Siliceous	
148	Ord	L			D			
149	Mis	IR			MC		Hunton	
150								
151	Ord	D						
152	Mis	IR						
153								
154	Ord	D						
155								
156	Pen	L			A	2	Siliceous	
157	Mis	IR			Af	7	Siliceous	
	S-D	D			Af			
158	Mis	IR			A		Siliceous	
159	Mis	IR			A		Siliceous	
160	Ord	L			A	2	Siliceous	
161	Ord	L			A	3	Siliceous	
162	Mis	IR			A	2	Siliceous	
163								
164	Ord	D	Cav	11				
165	Pen	L	Cav	12	D	7	Siliceous	
166	Ord	D	Cav	38	A	17	Pre-Cam	
167	Ord	D	Cav	20		1		3,742
168	Ord	D	Cav	3	D		Reagan	
169	Ord	D	Cav	19		1		
170	Ord	D	Cav	25	A	1		
171	Ord	D	Cav	43	D			
172	Ord	D	Cav	3	D	2		
173	Ord	D	Cav	24		1		
174	Pen	DR		30	ML	2	Siliceous	
175	Ord	D	Cav	26	A	1	Pre-Cam	O
176	Ord	D	Cav	6	D		Reagan	O
177	Ord	D	Cav					
178	Pre-Cam	S	Por	3	D	5	Pre-Cam	
	Pen	L	Cav	30				
179	Ord	D	Cav	19	A	1	Reagan	
180	Mis	IR		43	MC			
181	Pen	L	Cav	10	D	4	Reagan	
	Ord	D		21				
182	Ord	S	Por	20		2	Siliceous	
183	Pen	DR		6	MC			O
184	Ord	D	Cav	8	A			O
185	Ord	D	Cav	38	A	1	Pre-Cam	

TABLE 1.—(Continued)

Line Number	Field, Survey, Township, Range	Age, to End of 1936		Area Proved, Acres			
				Oil	Oil and Gas ^a	Gas	Total
		Years	Months				
186	Welch, 2-21-6.....	12	9	1,500			1,500
187	Wenke, 7-20-10.....	1	10	10			10
188	Wherry ²³ , 2-21-7.....	3	3	120			120
189	Rooks County.....						
190	Dopita, 31-8-17.....	2	9	40			40
191	Faubin, 12-6-18.....	10	10	10			10
192	Laton, 11-9-16.....	9	6	200			200
193	Webster, 15-8-19. 21-8-19.....	6	2	80			80
194	Westhusin, 11-9-17.....	1	2	10			10
195	Zurich, 26-10-19.....	1	3	60			60
196	Rush County.....						
197	Bison, 27-17-17.....	8	2			40	40
198	Otis, 10-18-16.....	6	9		3,600		3,600
199	Russell County.....						
200	Anschutz, 10-15-13.....		9	40			40
201	Atherton, 30-13-14.....	1	6	160			160
202	Benso, 9-14-15.....	10	40	40			40
203	Berrick, 6-15-13.....	1	1	80			80
204	Big Creek, 30-14-14.....	1	6	120			120
205	Boxberger, 36-15-15.....	1	1	160			160
206	Bunker Hill, 31-13-12.....	1	2	80			80
207	Coralena, 17-15-13.....	3	3	40			40
208	Dillner, 35-13-15.....	6	8	40			40
209	Donovan, 10-15-15.....	1	10	40			40
210	Dubuque, 34-15-12.....	1	2	80			80
211	Eichman, 34-15-13.....	1	8	600			600
212	Fairport, T. 11, 12 + 13. R. 15 + 16.....	13	2	3,600			3,600
213	Gideon, 8-15-14.....	6	6	40			40
214	Gorham ²⁴ , T. 13 + 14. R. 15.....	10	2	3,600			3,600
215	Gurney, 23-14-14.....	1	10	600			600
216	Hall ²⁷ , 30-14-13.....	5	2	300			300
217	Harbaugh, 25-14-15.....		10	300			300
218	Karst, 27-15-14.....	1	3	80			80
219	Letch, 34-14-13.....		6	40			40
220	Niedenthal, 23-14-15.....	2	5	300			300
221	Ochs, 23-15-14.....	7	2	400			400
222	Peterson, 12-14-15.....		2	40			40
223	Russell, 27-13-14.....	2	10	1,200			1,200
224	Sellens, 26-15-13.....	7	6	1,200			1,200
225	Steinert, 21-15-15.....		7	10			10
226	Sullivan, 2-14-15.....	1	9	1,000			1,000
227	Sullivan, 2-14-15.....						
228	Sullivan, 2-14-15.....						
229	Trapp ²⁸ , 30-15-13.....	10		1,000			1,000
230	Williamson, 9-14-14.....	11		40			40

²² Formerly called Thode.²⁶ Includes East Gorham, Dumler, Foster and Milberger.²⁷ Formerly Miller.²⁸ Includes North Trapp.

TABLE 1.—(Continued)

Line Number	Total Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells								
	To End of 1936	During 1935	During 1936	To End of 1936	During 1935	During 1936	Maximum Daily during 1936	Completed to End of 1936	During 1936		At End of 1936					
									Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas ^a	Producing Gas Only	Total Producing	
186	3,700,800	310,000	225,160										32			32
187	19,232	10,532	8,700										1			1
188	228,536	98,437	67,585										4			4
189		25,800														
190	4,006	2,106	1,900										2			2
191	4,020		4,020										1			1
192	186,605	18,394	25,228										3			3
193	37,449							2					1			1
194			0					1					1			1
195	21,890	2,585	19,305					3					3			3
196		1,827														
197				524				4								0
198	38,755	2,247	36,170	22,530				32					5		1	32
199	24,000,000	4,200,000	6,500,426													
200	22,426		22,426					2					2			2
201	120,124	1,561	16,488					1					1			1
202	6,311		103,575					6					6			6
203	25,074		6,311					1					1			1
204	67,395	663	25,074					3					3			3
205	60,440	900	66,732					5					5			5
206	12,628	2,000	59,540					4					4			4
207	5,904		10,628					2					2			2
208	61,154	1,543	5,904					1					1			1
209	14,943	3,800	0					2					0			0
210	57,891	1,391	11,143					1					1			1
211	224,420	6,748	56,500					4					3			3
212	11,971,217	1,025,000	217,672					13					13			13
213	25,390	6,442	0					4±					1			1
214	5,297,956	1,040,000	1,494,728					160					112			112
215	154,943	20,143	134,800					14					14			14
216	457,955	136,000	244,000					16					16			16
217	120,421		16,100					1					1			1
218	26,574	350	104,321					11					11			11
219	4,336		26,224					4					4			4
220	481,085	233,000	4,336					1					1			1
221	630,156	231,000	236,439					14					14			14
222	11,429		119,345					12					10			10
223	2,348,586	1,100,000	11,429					1					1			1
224	1,464,236	356,000	59,347					3					3			3
225	7,477		1,041,070					40					40			40
226	745,738	28,896	356,812					1					24			24
			7,477					1					1			1
			14,177					1					1			1
			149,747					1					1			1
227			295,702					46					46			46
228			241,988					2					1			2
			15,228					1					1			1
229	400,239		400,239					47					47			47
230	11,363		11,363					1					1			1

TABLE 1.—(Continued)

Line Number	Depth, Average in Feet		Oil Production Methods at End of 1936		Pressure, Pounds per Square Inch ^d		Character of Oil, Approx. Average during 1936			Character of Gas, Approx. Average during 1936		Producing Rock	
	Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells		Initial	Average at End of		Gravity A.P.I. at 60° F.	Sulphur, Per Cent	Base ^e	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Name
			Flowing	Pumping		1935	1936						
								Weighted Average					
186	3,415	3,370		32				33					Chat
187	3,373	3,360		1				42					Siliceous
188	3,380	3,358		4				32					Chat
189													
190	3,217	3,212		2				36					Oswald
	3,419	3,409						25					Siliceous
191	3,150	3,128		1				40					Oswald
192	3,261	3,228		3				40					Oswald
193	3,225	3,215						35					Oswald
	3,455	3,445		1				25					Siliceous
194	3,242	3,231		1									Oswald
195	3,349	3,340		3				36					Oswald
196													
197	3,578	3,573			915								Basal congl.
198	3,509	3,507		5	1,350	1,140	35						Reagan ²⁶
199													
200	3,327	3,311		2				37					Siliceous
201	3,055	3,008		1				31					Oswald
	3,289	3,284		6				40					Siliceous
202	3,096	3,030		1				37					Oswald
203	2,945	2,894		3				39					Oswald
204	3,184	3,180		5				37					Siliceous
205	3,151	3,147		4				37					Oswald
206	2,981	2,965		2				36					Oswald
207	2,881	2,790		1									Topeka
208	3,308	3,300		0				30					Siliceous
209	3,199	3,193		1				37					Oswald
210	3,278	3,275		3				40					Siliceous
211	3,326	3,316		13				36					Siliceous
212	2,962	2,950		147				42					Oswald
	3,217	3,211						38					Gorham
213	3,325	3,317		1				36					Oswald
214	3,057	3,027		112				38					Oswald ²⁹
	3,300	3,299						34					Gorham
215	3,006	2,675		14				38					Topeka
		3,001											Oswald
216	2,940	2,902		16				38					Oswald
	3,454	3,451						40					Basal congl.
		2,908		1				37					Oswald
217	3,185	3,179		11				41					Reagan
218	3,319	3,315		4				36					Siliceous
219	2,880	2,831		1				38					Oswald
220	3,250	3,246		14				40					Siliceous
221	3,378	3,364		10				36					Siliceous
222				1									Siliceous
223	3,204	3,195		3				41					Oswald
	3,286	3,280		40				36					Siliceous
224	3,097	3,088						37					Oswald
	3,365	3,352		24				38					Siliceous
225	3,097			1				35					Oswald
226	2,526	2,525		1				36					Tarkio
	2,799	2,780		1				39					Topeka
227	3,070	3,060		1				38					Oswald
	3,314	3,310		46									Gorham
228	3,332	3,330		2				37					Siliceous
				1									Lecompton
													Topeka, Oswald
229	3,253	3,252		47									Siliceous
230	2,550	2,522		1				35					Tarkio

²⁵ Gas also in Wabaunsee.²⁹ Also Tarkio, Topeka, Siliceous.

TABLE 1.—(Continued)

Line Number	Producing Rock					Number of Dry and/or Near-dry Holes to End of 1936	Deepest Zone Tested to End of 1936		Reference to Text ⁱ
	Age ^f	Character ^g	Porosity ^h	Net Thickness, Average in Feet	Structure ⁱ		Name	Depth of Hole, Ft.	
186	Mis	IR		45	A	9	Simpson		
187	Ord	D	Cav	13		1			
188	Mis	IR		22	MC	1	Siliceous		0
189									
190	Pen	L	Cav	5	A				
	Ord	D	Cav	10					
191	Pen	L	Cav	22					
192	Pen	L	Cav	33	A	4			
193	Pen	L	Cav	10					
	Ord	D	Cav	10					
194	Pen	L							
195	Pen	L	Cav	9	A	3	Simpson		
196									
197	Pen	DR		5	D		Pre-Cam		
198	Cam	S	Por	20	D		Pre-Cam		
199									
200	Ord	D	Cav	16					
201	Pen	L	Cav	47	A		Reagan		
	Ord	D		5					
202	Pen	L	Cav	66	A		Pre-Cam		
203	Pen	L	Cav	51			Pre-Cam		
204	Ord	D	Cav	4	A	1	Siliceous		
205	Pen	L	Cav	4			Siliceous		
206	Pen	L	Cav	16	A		Siliceous		
207	Pen	L	Cav	20					0
208	Ord	D	Cav	8	A				
209	Pen	L	Cav	6	A	1	Siliceous		
210	Ord	D	Cav	3	AC	2	Pre-Cam		
211	Ord	D	Cav	10	A				0
212	Pen	L	Cav	12	A	21	Pre-Cam		
	Pen	S	Por	6					
213	Pen	L	Cav	8		3			
214	Pen	L	Cav	30	D	13	Pre-Cam		
	Pen	S	Por	1					
215	Pen	L		5	A	2	Pre-Cam		
	Pen	L							
216	Pen	L		15	A				
	Pen	DR		3					
217	Pen	L	Cav	6	A				
	Cam	S	Cav						
218	Ord	D	Cav	4	A	1			
219	Pen	L	Cav	15	A		Pre-Cam		
220	Ord	D	Cav	4	A	1			
221	Ord	D	Cav	14	A	1	Pre-Cam		
222	Ord	D	Cav		A				
223	Pen	L	Cav	9	D	9	Pre-Cam		
	Ord	D	Cav	6					
224	Pen	L		9	A	6	Pre-Cam		
	Ord	D		13					
225	Pen	L	Cav						
226	Pen	L		1	A		Pre-Cam		
	Pen	L		19					
227	Pen	L		10	A				
	Pen	S		4					
228	Ord	D		2	A				
	Pen	L							
229	Pen	D		2	A				0
	Ord	D		1					
230	Pen	L	Cav	10					

pool. All these pools are in Russell County, on the north flank of the Central Kansas uplift (formerly called Barton Arch). The Topeka lime, which was added to the number of producing horizons in a previous year, continued to furnish additional amounts of oil and was found in several other pools.

At present these upper "pays" are insignificant from the standpoint of total recovery. The Siliceous lime of Ordovician age still heads the group as the most prolific producing level. It is followed by the Oswald lime of Pennsylvanian age. The Viola lime is gaining prestige because

TABLE 1.—(Continued)

Line Number	Field, Survey, Township, Range	Age, to End of 1936		Area Proved, Acres			
		Years	Months	Oil	Oil and Gas ^a	Gas	Total
231	<i>Scott County</i>						
232	Shallow Water, 15-20-33 W.....	2	1	160			160
233	<i>Sedgwick County</i>						
234	Bentley, 19-15-1.....	2	9	10			10
235	Cheney, 8-27-4.....	1	3	10			10
236	Cross, 26-25-1.....	7	9	160			160
237	Eastborough, 19-27-2 E.....	7	5	1,000			1,000
238	Goodrich, 16-25-1 E.....	8	1	700			700
239	Greenwich, 14-26-2 E.....	7	8	700			700
240	Robbins, 20-28-1 E.....	7	7	420			420
241	Schulte, 6-28-1.....	2	11	40			40
242	Valley Center, 1-26-1.....	8	5	1,500			1,500
243	<i>Stafford County</i>						
244	Gates, 27-21-13.....	3	8	320			320
245	Jordan, 15-25-14.....	2		10			10
246	Richardson, 31-22-11.....	6	3	1,200			1,200
247	Snider, 3-21-11.....		9	80			80
248	St. John, 23-24-13.....	1	9	40			40
249	<i>Sumner County</i>						
250	Caldwell, 17-35-3.....	7	8	160			160
251	Churchill, 25-31-2 E.....	10	6	1,000			1,000
252	Corbin, 23-34-2.....	9	6	40			40
253	Latta, 9-30-2.....	9	5		300		300
254	Oxford, 23-32-2 E.....	9	5	800			800
255	Padgett, T. 34 + 35 R. 2 E.....	10	3		1,800		1,800
256	Rutter, 21-33-2 E.....	10	6	40			40
257	Wellington, 33-31-1.....	7	1	1,200			1,200
258	<i>Trego County</i>						
259	Holcomb, 26-11-23.....		9	80			80
260	Wakeeney, 14-11-23.....	2	3	1,200			1,200
261	<i>Woodson County</i>						
262	Winterscheid, 15-23-14. 19-24-14.....	15		7,700			7,700
263	<i>Southwest County</i>						
264	Hugoton, Morton, Stevens, Grant, Haskell, etc.....	16				1,500,000	1,500,000

of the Lerado pool in southwestern Reno County and because of its possibilities in southwestern Kansas (Clark County). The discovery at the latter locality proved one of the most interesting of the year. One of the deep wells in the Morrison pool, now 8 years old, encountered a large flow of oil at 6467 ft. in the Viola. Many operators and geologists feel that this proves up large areas in southwestern Kansas and northwestern Oklahoma for future exploration and exploitation. The large flow of gas found in the western extension of the Cunningham pool, in Pratt County, within the Viola is probably of local significance only. In the same

TABLE 1.—(Continued)

Line Number	Total Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells								
	To End of 1936	During 1935	During 1936	To End of 1936	During 1935	During 1936	Maximum Daily during 1936	Completed to End of 1936	During 1936		At End of 1936					
									Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas ^b	Producing Gas Only	Total Producing	
231								3								3
232	33,981	24,180	9,301													
233	38,250,000	3,050,000	1,641,543													
234	5,115	2,057	0					1								1
235	3,700	2,245	0					1								0
236	38,500	12,500	0					4								4
237	6,947,821	396,000	304,798					56						49		49
238	1,661,057	159,073	109,920					13						13		13
239	8,069,774	760,000	499,881					61						43		43
240	2,428,132	1,027,000	442,782					56						55		55
241	65,489	54,000	11,560					4						0		0
242	18,756,611	593,000	577,400					135						75		75
243			715,106													
244	268,365	120,000	66,577					4						4		4
245			0					1						1		1
246	1,631,791	558,000	487,493					27						27		27
247	43,360		18,400					1						1		1
			24,960					3						3		3
248		1,139	22,312					2						1		1
249	34,700,000		2,382,372													
250	1,121,171	75,396	44,609					8						4		4
251	17,600,000	350,000	396,000											60		60
			87,349											6		6
252	30,264		0					4						1		1
253	336,474	36,494	32,000											5	4	9
254	12,684,000	785,500	48,156											30		30
			1,622,066													
														57		57
255	1,506,605	125,071	104,953	3,430										23	18	41
256	15,196	0	0					1						0		0
257	1,345,806	272,508	667,441					52						52		52
258																
259	14,883		14,883					2						2		2
260	106,758	22,000	75,258					8						8		8
261																
262		304,000	310,876											204		204
263																
264				103,150	20,000	21,000	100	181	35	1					180	180

category must be placed the discovery of the largest flow of gas (75 million cubic feet) from any western Kansas well, which was encountered in the Pulliam well near Lyons, in Rice County. In this well it was the Siliceous that was found productive, and this is the first gas production from this very widespread oil-producing zone.

Additional light was shed on the correlation of the "basal sand" of western Kansas. It is now known definitely that a sand that lies stratigraphically below the Siliceous produces in certain Barton County pools

TABLE 1.—(Continued)

Line Number	Depth, Average in Feet		Oil Production Methods at End of 1936	Pressure, Pounds per Square Inch ^d		Character of Oil, Approx. Average during 1936			Character of Gas, Approx. Average during 1936		Producing Rock	
	Number of Wells		Average at End of		Gravity A.P.I. at 60° F.					Name		
	Flowing	Pumping	Initial	1935	1936	Weighted Average	Sulphur, Per Cent	Base ^e	B.t.u. per Cu. Ft.		Gal. Gasoline per M. Cu. Ft.	
231												
232	4,686	4,670		3				26			Vaniman	
233												
234		2,911		1				34			Kansas City	
235	4,017	4,006		0				38			Viola	
236	2,730	2,690		4				35			Kansas City	
237		2,927		49				44			Chat, Misener	
		3,235									Viola	
238		2,616		13				35			Kansas City	
		3,350						38			Misener	
239	2,868	2,865		43				39			Chat	
		3,327						42			Viola & Wilcox	
240		3,090		55				42			Mis. lime	
241	3,668	3,666		0							Wilcox	
242	3,368	2,600		75				43			(Kansas City	
		3,366									Misener	
243											Viola	
244	3,714	3,698						38			Siliceous	
245	3,727	3,722						37			Oswald	
246	3,599	3,537						41			Siliceous	
247	3,138	3,111						36			Oswald	
	3,343	3,324						42			Siliceous	
248	4,087	3,513						33			Kansas City	
		4,075						35			Siliceous	
249												
250	4,784	4,778						47			Wilcox	
251		1,820						37			Stalnaker	
		2,335						36			Kansas City	
252	4,498	4,490						46			Wilcox	
253	2,031	2,015									Topeka	
	3,046	3,042						40			Oswald ³⁰	
254		2,020						37			Stalnaker, Layton	
		2,400										
		2,890						38			Siliceous ³¹	
255	3,502	3,474						38			Chat ³²	
256		3,315									Chat	
257	3,666	3,655	52					42			Chat	
258												
259		3,602						40			Oswald	
260	3,627	3,619						39			Oswald	
261												
262											Bartlesville	
263											Mis. lime	
264	2,775	2,680			435	425	422			1,030	425	Big Blue

³⁰ Two horizons 150 ft. apart.³¹ Also Howard, Hoover and Severy.³² Also small production in Siliceous.

(see Table 1). This sand is therefore called "Reagan" although geologists are fully aware that it may be younger than the Reagan of Oklahoma and may actually correspond to the Roubidoux or even the Gunter of Missouri, both of which are of Ordovician age. By some geologists the name Lamotte (taken from Missouri) is preferred to Reagan. Another basal sand is the Pennsylvanian basal conglomerate. This is not ordinarily a true sand, but usually consists of detrital rubble of Ordovician and Mississippian rocks washed into the Pennsylvanian sea from a near-by hill. Most commonly it contains chert fragments embedded in a red

TABLE 1.—(Continued)

Line Number	Producing Rock					Number of Dry and/or Near-dry Holes to End of 1936	Deepest Zone Tested to End of 1936		Reference to Text ^j
	Age ^f	Character ^g	Porosity ^h	Net Thickness, Average in Feet	Structure ⁱ		Name	Depth of Hole, Ft.	
231	Mis	L	Cav	16	A	1	Siliceous		
232									
233									
234	Pen	L	Cav		MC		Ordovician		
235	Ord	L	Cav		A		Siliceous		
236	Pen	L	Cav		MC	2	Ordovician		
237	Mis	IR & L	Por		D	12	Siliceous		
	Ord	L	Cav						
238	Pen	L	Cav		D	7	Siliceous		
	Mis	D	Cav						
239	Mis	IR	Cav		D	21	Siliceous		
	Ord	L & S							
240	Mis	L	Cav		AC	16	Siliceous		
241	Ord	S	Por		MC	4	Siliceous		
242	Pen	L	Cav		D	17	Siliceous		
	Mis	L							
	Ord	D							
243									
244	Ord	D	Cav	16	A	4			
245	Pen	L					Siliceous		
246	Ord	D	Cav	62	Af	1			
247	Pen	L	Cav	27	A				
	Ord	D		19					
248	Pen	L	Cav	12	A				
	Ord	D							
249									
250	Ord	S	Por	6	D	1	Siliceous		
251	Pen	S	Por	60	Df	13	Pre-Cam		
	Pen	L	Cav						
252	Ord	S	Por	8		3	Siliceous	4,805	
253	Pen	L		16		6	Siliceous	4,367	
	Pen			4					
254	Pen	S	Por			20			
	Ord	D	Cav						
255	Mis	IR		28	AC	12	Siliceous	3,785	
256	Mis	IR			AC	2	Siliceous	3,700	
257	Mis	IR		11	MC		Siliceous		
258									
259	Pen	L							
260	Pen	L		8			Siliceous		
261									
262	Pen	S							
	Mis	L							
263									
264	Perm	L	20	45	MC		Mississippian	5,500	A

TABLE 2.—*Summary of Drilling Operations in Kansas*

Important Wildcats Drilled in 1936

	County and Field	Location			Total Depth, Ft.	Surface Formation
		Sec.	Twp.	Rg.		
		Survey	Lat.	Long.		
1	Barton County					
2	Ainsworth.....	33	16 S.	13 W.	3395	Cretaceous
3	Bloomer.....	36	17 S.	11 W.	3281	Quaternary
4	Ehly.....	15	16 S.	12 W.	3332	Cretaceous
5	Hiss.....	31	20 S.	13 W.	3290	Quaternary
6	Rick.....	1	19 S.	11 W.	3355	Quaternary
7	Susank.....	16	16 S.	13 W.	3389	Cretaceous
8	Butler County					
9	Brandt.....	15	28 S.	7 E.	2700	Big Blue Perm.
10	McCullough.....	1	28 S.	6 E.	3175	Big Blue Perm.
11	Clark County					
12	Morrison.....	17	32 S.	21 W.	6484	Permian Cim.
13	Cowley County					
14	David.....	35	30 S.	4 E.		Big Blue Perm.
15	Genda Springs.....	11	34 S.	3 E.	3320	Wellington
16	Murphy.....	8	35 S.	3 E.		Wellington
17	Sherwood.....	11	31 S.	4 E.		Big Blue Perm.
18	Ellis County					
19	Antonino.....	26	14 S.	19 W.	3710	Cretaceous
20	Catherine.....	3	13 S.	17 W.	3362	Cretaceous
21	Haller.....	10	11 S.	18 W.	3045	Cretaceous
22	Kraus.....	22	14 S.	19 W.	3740	Cretaceous
23	Madden.....	26	15 S.	18 W.	3600	Cretaceous
24	Marshall.....	36	11 S.	18 W.	3650	Cretaceous
25	Penny Wann.....	13	15 S.	20 W.	3658	Cretaceous
26	Solomon.....	28	11 S.	19 W.	3632	Cretaceous
27	Ubert.....	12	13 S.	18 W.	3707	Cretaceous
28	Walters.....	2	12 S.	18 W.	3165	Cretaceous
29	Bemis.....	15	11 S.	17 W.	3380	Cretaceous
30	Victoria.....	3	14 S.	17 W.	3560	Cretaceous
31	Ellsworth County					
32	Breford south.....	18	17 S.	10 W.	3310	Cretaceous
33	Harvey County					
34	Warkentine.....	1	23 S.	2 W.	3000	McPherson
35	McPherson County					
36	Canton North.....	26	18 S.	1 W.	2832	Wellington
37	Ness County					
38	Thompson.....	13	18 S.	26 W.	4527	Tertiary
39	Pawnee County					
40	Pawnee Rock.....	13	20 S.	16 W.	3841	Cretaceous
41	Rice County					
42	Bowman.....	22	19 S.	10 W.	3305	Quaternary
43	Doran.....	13	19 S.	10 W.	3311	Quaternary
44	Edwards.....	3	18 S.	8 W.	3282	Quaternary
45	Empire.....	8	20 S.	9 W.	3291	Quaternary
46	Haferman.....	6	19 S.	9 W.	3216	Quaternary
47	Hauschild.....	15	21 S.	7 W.	3372	Quaternary
48	Mantel.....	18	20 S.	10 W.		Quaternary
49	Ponce.....	28	21 S.	7 W.	3431	Quaternary
50	Saxman.....	5	21 S.	7 W.	3337	Quaternary
51	Schatts.....	33	19 S.	10 W.	3320	Quaternary
52	Rooks County					
53	Faubin.....	12	6 S.	18 W.	3160	Cretaceous
54	Westhusin.....				3050	
55	Russell County				3240	Cretaceous
56	Anschuts.....	10	15 S.	13 W.	3327	Cretaceous
57	Benso.....	9	14 S.	15 W.	3036	Cretaceous
58	Coralena.....	17	15 S.	13 W.	2881	Cretaceous
59	Harbaugh.....	25	14 S.	15 W.	3150	Cretaceous
60	Letch.....	34	14 S.	13 W.	2950	
61	Peterson.....	12	14 S.	15 W.	2880	Cretaceous
62	Steinert.....	21	15 S.	15 W.	2095	Cretaceous
63	Trapp.....	30	15 S.	13 W.	3253	Cretaceous
64					3064	
65	Gurney south.....	26	14	14	3170	Cretaceous
66	Williamson.....	9	14 S.	14 W.	2550	Cretaceous

TABLE 2.—(Continued)

Important Wildcats Drilled in 1936

	Deepest Horizon Tested	Drilled by	Initial Production per Day		Discovered by
			Oil, U. S. Bbl.	Gas, Millions Cu. Ft.	
1	Siliceous lime	Vernon O. & G.	1241		Core drill.
2	Siliceous lime	Yarnell, Carlson Spencer	470		Wildcat.
3	Reagan ¹	Vickers Petroleum Co.	311		Subsurface.
4	Oswald	Simpson, Noble Atlantic	969		Seismograph.
5	Siliceous lime	Rose-Spring Drilling	937		
6	Siliceous lime	C. L. Price et al.	939		Wildcat.
7	Mississippian chat	Armer et al.	195		Core drill.
8	Wilcox	National Refining	108		Subsurface.
9	Viola lime	Olson Drilling	2358		Subsurface.
10	Bartlesville				
11	Bartlesville	Shawver and Wilt	120		
12	Chat				
13	Bartlesville	Roth and Fourot	215		
14	Basal conglomerate	Twin Drilling	410		Core drill.
15	Oswald lime	Harris & Haun et al.	676		
16	Topeka lime	Kansas Dev. Co.	531		
17	Penn. Basal conglomerate	Vickers Petroleum Co.	259		Seismograph.
18	Siliceous lime	Bridgeport Machine	400		
19	Siliceous lime	Lario Oil and Gas	800		
20	Basal conglomerate	Bradley et al.	420		Seismograph.
21	Siliceous lime	Jones Bros., Carpenter, et al.	600		Seismograph.
22	Siliceous lime	Bridgeport Machine	416		Subsurface.
23	Topeka lime	Lario Oil and Gas	1159		Core drill and subsurface.
24	Siliceous lime	Margay Oil Co.	1353		
25	Siliceous lime	Twin Drilling	412		
26	Siliceous lime		955		
27	Mississippian chat	West Kans. Dev. Co.	569		Core drill and subsurface.
28	Mississippian chat	Empire O. & R.	825		Core drill and seismograph.
29	Mississippian chat	Continental Oil	684		Core drill and seismograph.
30	Siliceous lime	Simpson & Noble	257		Seismograph.
31	Siliceous lime	Simpson & Noble	58		
32	Siliceous lime	Stark et al.	1366		Wildcat.
33	Siliceous lime	C. E. Skiles et al.	550		Seismograph.
34	Siliceous lime	Empire O. & R.	435		Seismograph.
35	Siliceous lime	Rose-Spring et al.			
36	Siliceous lime	Shell et al.	1719		Seismograph.
37	Basal conglomerate	Douglas O. & G.	624		Wildcat.
38	Siliceous lime	Rose-Spring	418		Subsurface.
39	Mississippian chat	Day et al.	135		Wildcat.
40	Basal conglomerate	Sage & Douglass	1135		Wildcat.
41	Siliceous lime	Hartman, Blair, Texas Co.	440		Subsurface.
42	Oswald	Gillispie & Sons	306		Core drill.
43	Oswald	Dean & Kiskaddin	504		Core drill.
44	Siliceous lime	Murphy, Phillips	487		Subsurface.
45	Oswald lime	Cent. Pet. Co.	292		
46	Topeka	Coralena Pet. Co.	2000		Wildcat.
47	Siliceous lime, Oswald lime	Hartman & Blair	788		Subsurface
48	Oswald	Darby Petroleum	419		Core Drill.
49	Siliceous lime	Braden & McClure	840		
50	Oswald	Lario Oil and Gas	729		Surface.
51	Siliceous lime		1200		
52	Oswald	Coralena Oil Co.	598		
53	Topeka				
54	Basal conglomerate	Braden and McClure	220		
55	Tarkio lime	R. C. Tarrant	243		Wildcat.

¹ May be basal conglomerate.

clay matrix. Locally large percentages of sand and even shale and limestone fragments are present. When a layer of sandstone or conglomerate of quartz pebbles is found, it is very difficult to decide whether production occurs in the Pennsylvanian or some older horizon. Such a situation exists in the Antonino pool of Ellis County.

Even more confusing are situations where the Pennsylvanian basal conglomerate lies directly upon the Mississippian chat. Typical chat consists of the insoluble residues left behind when the Mississippian limestone was subject to prolonged erosion. These residues are predominantly chert fragments and red clay. In the Hauschild pool, of Rice County, one of the 1936 discoveries, the Pennsylvanian basal conglomerate overlies the chat. This pool eventually will merge with the near-by Wherry, Alberta Johnson, Theede and Saxman pools. The area has been one of the "hot spots" during 1936, partly because of the large production from some of the wells (up to 15,000 bbl. per day) and partly because none of the major companies had an original interest there.

HOT SPOT OF 1936

Another place in which development has progressed at a feverish pace during the year is the Trapp area of southern Russell County. This

TABLE 2.—(Continued)

Important Wildcats Drilled in 1936					
	County and Field	Location			Surface Formation
		Sec.	Twp.	Rg.	
		Survey	Lat.	Long.	
	Stafford County				
53	Jordan.....	15	25 S.	14 W.	3725 Quaternary
54	Snider.....	3	21 S.	11 W.	3343 Quaternary
55	St. John.....	23	24 S.	13 W.	4075 Quaternary
	Trego County				
56	Holcomb.....	26	11 S.	23 W.	3654 Cretaceous
57	Gas Pools.....				
	Finney County				
59	Hamlin.....	31	24 S.	34 W.	2700 Quaternary
60	Jones.....	34	26 S.	34 W.	2764 Quaternary
	Haskell County				
61	Elliott.....	30	29 S.	33 W.	2682 Tertiary
62	Nilson.....	21	28 S.	32 W.	2745 Tertiary
63	Larson.....	28	28 S.	33 W.	2771 Tertiary
	Pratt County				
64	Gilchrist.....	7	28 S.	11 W.	4245 Tertiary
	Rice County				
65	Lyons.....	35	19 S.	8 W.	3385 Quaternary
66	Old pools.....				
67	New Horizon.....				
	Elk County				
68	Webb.....	25	31 S.	10 E.	2286 Pennsylvanian

pool together with North Trapp, Sellens, Eichman, Ochs, and Coralena, all of which probably will merge with it, had 75 wells at the end of the year. The Silica area, which started out as the Steckel and Isern pools, saw very rapid development, ending the year with 175 wells. It will probably merge with the Peter and Langfeld pools to the south and the Schartz pool to the east. Production comes from the Siliceous, which occupies a topographic plateau interrupted by small local sinkholes. The good porosity has given wells with large initial production. This area vied with the prolific Burrton area during the year for first place in total production.

The Silica area lies only a few miles west of the Chase pool, which saw such rapid development in 1935. It, in turn, lies on the trend of the Lorraine pool, which lies in southern Ellsworth County, and is being actively drilled. More scattered development, but none the less inten-

TABLE 2.—(Continued)

Important Wildcats Drilled in 1936

	Deepest Horizon Tested	Drilled by	Initial Production per Day		Discovered by
			Oil, U. S. Bbl.	Gas, Millions Cu. Ft.	
53	Oswald	Atlantic Oil Co. L. A. Ferris	575		Seismograph. Subsurface.
54	Siliceous lime		737		
55	Siliceous lime				
56	Oswald lime	Continental Oil	495		Surface.
57					
58					
59	Big Blue	Lone Star State Helmerich, Payne		$\frac{3}{4}$	
60	Big Blue			$3\frac{1}{4}$	
61	Big Blue	Helmerich, Payne Kuhn Bros. et al. Helmerich, Payne			
62	Big Blue				
63	Big Blue				
64	Viola lime	Skelly, Empire, Gulf, Tidewater		50	Core drill and seismograph.
65	Siliceous lime	Simpson & Noble		75	Seismograph.
66					
67					
68	Siliceous lime	Diller Oil Co.	1000		

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1936.....		
Number of oil wells completed during 1936.....	1214	54
Number of gas wells completed during 1936.....	61	7
Number of dry holes completed during 1936.....	446	

sive, has taken place in Ellis County. Less than two years ago it had three pools (Hadley, Shutts and Yocemento) but at the close of 1936 there were 16 pools and 69 wells. Since many of these pools are one-well pools, much drilling may be expected during the coming year.

WATER DISPOSAL

The problem of water disposal has become a major problem. During the year many wells were drilled with the express purpose of providing an outlet for ever increasing quantities of salt water. A common procedure is to drill a deep, noncommercial well deeper into the producing horizon or into the Reagan sand. Before the water is allowed to enter the porous disposal zone it is treated in surface ponds or tanks in order to remove materials which might clog the formation. Available data indicate that in western Kansas the Dakota sandstone of Cretaceous age and also the salt zone (see Fig. 1) in the Permian Wellington are capable of absorbing large amounts of brine. Important also is the fact that they will take the water by gravity and that pressure is rarely needed. In some cases the capacity for water absorption is remarkably large. For instance in the Greenwich pool of Sedgwick County one well is able to assimilate 10,000 barrels per day.

REPRESSURING AND OTHER INTERESTING DATA

Intimately bound up with water disposal is the problem of repressuring. Many operators believe that much of the oil left underground may be obtained with economic profit by water drive. Each year more properties in the shallow districts of eastern Kansas are being flooded. With the present low prices for crude, not all of these ventures result in a profit. Besides Chautauqua, Elk, Montgomery and other eastern counties, where the sands are shallow and the fields are old, flooding has been started in Butler, Greenwood, Sumner and McPherson Counties. In most of these gravity does the work, but in a few additional pressure is used.

During 1936 one new county was added to the list of oil-producing counties. Pawnee County, which lies west of Stafford, now has one well in sec. 13 T. 20 S., R. 16 W. with a potential of 257 bbl. from the Siliceous lime. Production was found at a depth of 3815 feet. The pool farthest north in the state,—the Faubin pool, in Rooks County—was discovered during 1936 (12.-6 S.-18 W.), which found production in the Oswald lime at a depth of 3128 ft. Not less interesting is the revival of drilling in eastern Kansas, where the search for deeper horizons has not been abandoned. On Oct. 23, 1936, the Diller Oil Co. drilled in a 1000-bbl. well in sec. 25, T.31 S., R.10 E. (Webb pool of Elk Co.), finding the Siliceous at a comparatively shallow depth. Subsequently three other producers were drilled into the same producing horizon. The potential rating of these wells is 5500 bbl. without acid treatment. Other similar wells were

drilled by the Sagamore Oil Co. in Chautauqua County and by Denman Bros. in Elk County. In the old Longton gas area of Chautauqua County deeper drilling into the Mississippi lime has been rewarded by the finding

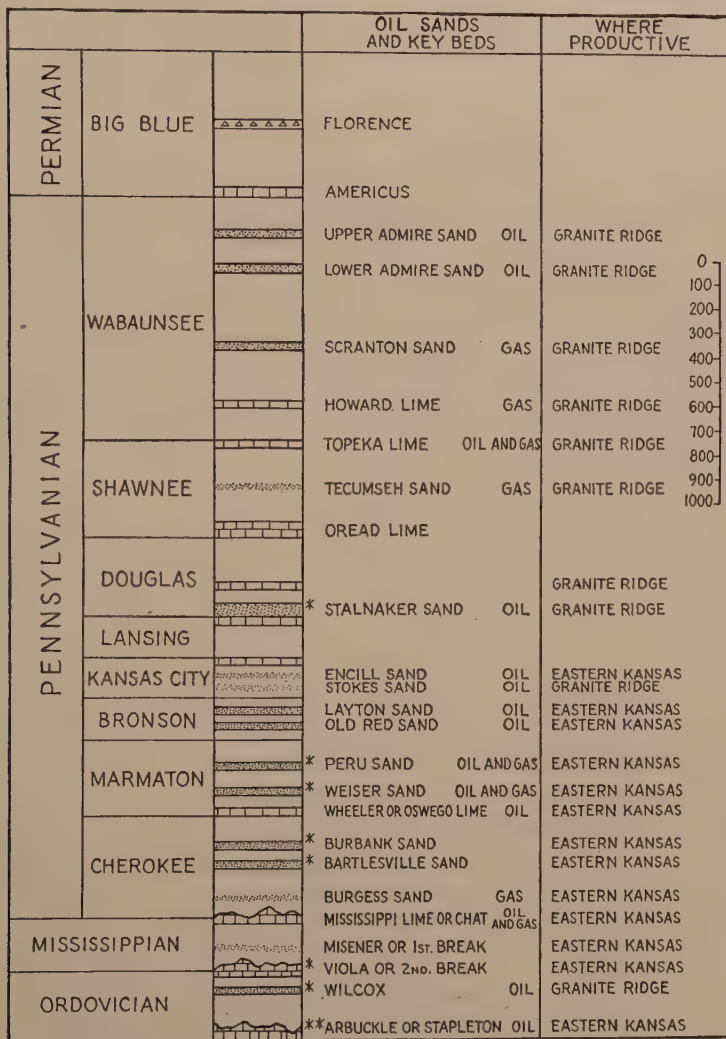


FIG. 2.—OIL-PRODUCING ZONES OF EASTERN KANSAS.

Drawn by Charles Matthews from data prepared by the author. Stars indicate most important producing horizons.

of important oil production. The first well was drilled in sec. 14, T.33 S., R.12 E., not far from the city of Sedan. It encountered oil at 1743 ft. some 150 ft. below the top of the Mississippi lime. Many similar Mississippi lime "highs" are known in southeastern Kansas and it is entirely probable that additional areas will be brought into production. (See Fig. 2.)

ACKNOWLEDGMENTS

The author wishes to state that he received information for Table 1 and Table 2 from many geologists in Wichita and other parts of Kansas. Marvin Lee, technical adviser of the Kansas State Corporation Commission, furnished the production figures for 1936 for practically all pools listed in Table 1. He also permitted the author to examine his personal production maps to determine the productive area for each pool. Edward Koester, geologist for Darby Oil Co., checked most of the data on Table 1 and made many corrections and additions. He also furnished most of the information on structure. Granville Tierney, of the Amerada Petroleum Corporation, very kindly permitted the author to use his figures showing production of fields in western Kansas up to the end of 1935. George Berry of the Empire Oil Co., furnished all the information on the El Dorado, Augusta and Haverhill pools, besides additional data on parts of Butler County. Mr. H. C. Walton, Superintendent of the Missouri Valley Gas Co., furnished the data on the Hugoton gas field of southwestern Kansas.

Oil and Gas Development in Kentucky in 1936

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DURING the year 1936 improvement in the oil industry in Kentucky continued at about the same rate as shown by that of the year 1935 over the year 1934.

The development of several new pools in western Kentucky and the increase in the application of repressuring methods to the old fields of eastern and to a lesser extent of western Kentucky increased the total production to 5,481,227 bbl., as compared to 5,175,054 produced in 1935. The principle sources of this increased production are the Livermore field and the new Bates Knob field in McLean County, in western Kentucky, and the result of repressuring operations in the "Corniferous" pools of Lee, Powell, Wolfe, Morgan and Estill Counties and the "Weir" sand (of Mississippian age) fields of Magoffin, Lawrence and Johnson Counties in northeastern Kentucky. The last named fields have a producing sand especially adaptable to these methods.

DRILLING

No new fields were opened in eastern Kentucky during the year. All new drilling was confined to pressure wells and new oil wells to complete patterns around the intake wells. Owing to the relatively low "initial" or flush production of the wells in this section—even though the ultimate recovery per acre is as large—higher prices for crude will have to prevail before extensive search for new fields is begun; as in northwestern Kentucky, where active exploratory work has been carried on as in the several preceding years, resulting in numerous new and prolific, although comparatively small fields.

In this section approximately 500 new oil wells drilled in the Owensboro field, embracing several pools in Ohio, Hancock, Daviess, McLean, Henderson, Webster and Nuhlenberg Counties in the northwestern part of the state. The total oil production for this field during 1936 exceeded by many thousand barrels the 2,821,722 bbl. produced in 1935. In these fields the producing sands range from the middle Missis-

Manuscript received at the office of the Institute March 15, 1937.

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TABLE 1.—*Oil and Gas Production in Kentucky*

Line Number	Field, County	Age, Years to End of 1936	Area Proved, Acres				Total Oil Production, Bbl.
			Oil	Oil and Gas ^a	Gas	Total	To End of 1936
1	Big Sinking, Lee, Estill, Powell, Wolfe.....	19	14,047			14,047	36,617,xxx
2	Ida May, Lee.....	12	377			377	571,xxx
3	Pebworth, Owsley.....	13	60			60	68,xxx
4	Roes Creek, Estill.....	19	468			468	765,808
5	Goosey, Lee.....	16					75,xxx
6	Trabue, Lee.....	7					98,xxx
7	Ashley, Powell.....	19	1,091			1,091	2,939,xxx
8	Irvine, Estill.....	21	4,722			4,722	11,822,xxx
9	Wagesville, Estill.....	19	400			400	406,842
10	Campton-Stillwater, Wolfe.....	24	1,447			1,447	644,423
11	Buffalo Creek oil pool, Owsley.....	14	12			12	27,xxx
12	Island Creek, Owsley.....	11		20		20	9,899
13	Olympia, Bath.....	19 ²					
14	Menfee oil pool, Menfee.....	17 ³					231,835
15	Ragland oil pool, Bath, Rowan.....	36 ⁴					258,930
16	Cannel City, Morgan.....	24	600			600	377,829
17	Oil Springs, Johnson, Magoffin.....	17	6,100			6,100	8,812,509
18	Burning Fork, Magoffin.....	14	918			918	1,652,853
19	Blaine, Lawrence, Johnson.....	18	6,820			6,820	14,583,173
20	Elna, Johnson.....	16					1,512,916
21	Louisa pool, Lawrence.....	24	1,222		600	1,222	1,496,948
22	Ambrose-Weller, Ohio.....	11	600			600	3,656,500
23	Isonville, Elliott.....	20	100	46	2,000	2,146	80,748
24	Big Sandy Oil, Floyd, Knott, Martin.....	21	200			200	146,xxx
25	McKinney, Lincoln.....	17					4,502
26	Wayne, Wayne, McCreary.....	39	8,522			8,522	4,357,717
27	Logsdon Valley, Le Grande, Bonnieville, Hart.....	6	2,922			2,922	5,838,030
28	Livermore, McClean.....	1 Yr. 4 Mo.	545		10	555	1,016,907
29	Barrett Hill, McClean.....	7	250			250	797,864
30	Owensboro, Davies, Ohio, McClean, Hancock, Breckenridge.....	18	10,800			10,800	25,xxx,xxx
31	Henderson, Henderson.....	6	218			218	474,813
32	Muhlenberg, Muhlenberg.....	7					245,692
33	Bowling Green, Allen, Warren, Simpson.....	18					12,035,561
34	Barren, Barren.....	17	3,667			3,667	2,421,711
35	Floyd gas field, Floyd.....	33	7		228,275	228,275	
36	Pike County gas fields, Pike.....	6			57,200	57,200	
37	Martin, Martin.....	39			80,300	80,300	
38	Knott, Knott.....	31			98,000	98,000	

^a Footnotes to column heads and explanation of symbols are given on page 291.² Depleted, abandoned since 1920.³ Depleted, abandoned 1930.⁴ Depleted, abandoned 1931.⁷ See Big Sandy oil field. This includes the few oil wells encountered in the Floyd, Martin, Pike, and Knox County gas fields which are referred to as the Big Sandy gas field.

TABLE 1.—(Continued)

Line Number	Total Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
	During 1935	During 1936	Daily Average during Nov. 1936	To End of 1936	During 1935	During 1936	Maximum Daily during 1936	Completed to End of 1936	During 1936		At End of 1936				
									Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas ^a	Producing Gas Only	Total Producing
1	64x,xxx	657,777 ¹	1,80x					2,4xx	1x	xx	0	2,3xx			2,xxx
2	59,xxx	49,xxx	15x					1xx				97			97
3	2,896	2,xxx	6					15				15			15
4	20,733	17,192						18x				18x			6x
5	1,xxx	1,xxx						13				13			411
6	10,xxx	11,xxx						15				15			915
7	5x,xxx	51,xxx	15x					523				523			xx
8	15x,xxx	152,xxx	4xx					1,1xx				9xx			xx
9	7,766	21,476	3					100				100			3x
10	5,803	8,864	20					275				275			6x
11	5,xxx	2,500	2x					7			3	4			4
12	0	0	0					6	0	0	2			0	0
13								20							0
14				100				150							0
15												100			0
16	1,011	678	2					75	0	14		75			10
17	217,639	218,066	56x								1,055	1,055			1,033
18	63,933	59,110	160					159				159			159
19	498,301	472,875	12x					1,118	0	0		1,118			1,118
20	42,900	43,930	120					250				250			230
21	38,438	36,954	9x					286			12	286			234
22	109,500	327,000	891					190	0			190			
23	3,227	2,164	7				40				3	24	4	8	11
24	2,xxx	36,793	200					44	5		13	39			13
25	0	0						8	0	0 ⁵		4		4	0
26	32,854	31,104	8x					1,451			1,451				6xx
27	279,074	217,449	1,8xx					1,2xx				1,0xx		2xx	9xx
28	23,171	993,736	2,749	0		0		169	164	0		163		Shutin 1	169
29		91,570	251					55	2						57
30	3,953,037	3,xxx,xxx	2,xxx					3,200							2,xxx
31	61,590	60,004	146					63				63			63
32	26,166	22,554	5x					20				20			20
33	216,234	186,876	5xx					2,026				1,xxx			1,xxx
34	49,198	66,900	14x								791				
35					y	y	y	1,202	45	1x				1,1xx	1,1xx
36					y	y	y	175	20	0	1x			175	16x
37					y	y	y	y	253	40	1x			24x	24x
38					y	y	y	y	182	22					182

¹ To obtain runs for each pool is nearly impossible; runs being available by county only. [See *Trans. A.I.M.E.* (1936) 118, 269.] Big Sinking pool, located in all four counties produced as follows:

	1935, Bbl.	1936, Bbl.
Lee.....	610,968	599,108
Estill.....	180,298	214,474
Powell.....	98,968	103,788
Wolfe.....	19,999	29,255

* Field has been abandoned for several years.

* During 1931, one well producing from the Ordovician created a great deal of excitement. This well is reported to have produced over 1000 bbl. per day for a few days. It is now reported producing over 100 bbl.

TABLE 1.—(Continued)

Line Number	Depth, Average in Feet		Oil Production Methods at End of 1936			Pressure, Lb. per Sq. In. ^a		Character of Oil, Approx. Average during 1936					Character of Gas, Approx. Average during 1936		
	Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells		Injection into Reservoir	Average at End of		Gravity A.P.I. at 60° F.			Sulphur Per Cent	Base ^b	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	
			Flowing	Pumping		Initial	1935	1936	Maximum	Minimum					Weighted Average
1	700-1,200	650-1,150		2,xxx	Air				42	37	40	P			
2	1,000-1,200	975-1,175		97								P			
3				15								P			
4	550- 900	520- 870		6x								P			
5				11											
6	940-1,140	900-1,100		15					42	40	41	P			
7	600-1,000	550- 950		4xx								P			
8	120-1,000	85- 960		9xx											
9	100- 400	75- 375		3x	Air							P			
10				6x											
11	1,125	1,110		4					42.8	40.8	41.8	P			
12										39		P			
13															
14	1,040-1,250	1,020-1,230													
15	650- 850	625- 825													
16	1,800-2,000	1,780-1,980		10											
17	900-1,260	860-1,220		1,033	Air	180	300	300	38	34	36.5	P			
18	1,080-1,400	1,040-1,360		159					38	36	36.5	P			
19	760-1,060	700-1,000		1,118	Air	550		360	38	34	36.5	P			
20	640-1,100	600-1,060		230					38	34	36.5	P			
21	1,600-1,900	1,575-1,875		234					40	37	38.5	P			
22	725	650- 700		190				Vacuum 10 Pts.	35.9		35.9				
23				11											
24	1,000-1,500	950-1,475	10	3							0.17	P			
25	121- 360	101- 390										P			
26	400- 700	385- 680		6xx											
27	700- 850	780-1,300		9xx								P			
28	1,400	1,300-1,400		168			250	50	34.5		34.5				
29	1,250	800-1,200		57		320	80	74	37	34	35.5				
30	600-1,300			2,xxx					35						
31				63											
32	1,250-1,700			20											
33				1,xxx											
34															
35	400-3,500	900-3,100											1,150		
36	*												1,150		
37	1,100-3,250	700-3,000								34			1,150		
38	1,300-3,500	1,250-3,000											1,150		

^a Gas-producing horizons in Pike County run from 10 to 20 per cent deeper than in Floyd County. The Devonian shales also thicken at average rate of 20 ft. per mile to the southeast.

TABLE 1.—(Continued)

Line Number	Producing Rock						Number of Dry and/or Near-dry Holes to End of 1936	Deepest Zone Tested to End of 1936		
	Name	Age ¹	Character ²	Porosity ³	Net Thickness, Average in Feet	Structure ⁴		Name	Depth of Hole, Ft.	Reference to Text ⁵
1	Corniferous	Dev, Sil	Ls	Por	30	MC	3zz	Trenton	2,xxx	
2	Corniferous	Dev	Ls	Por	20±	MC	4x	Devonian		
3	Corniferous	Dev	Ls	Por	20±	MC	1x	Devonian		
4	Corniferous	Dev	Ls	Por	20±	T	3x	Ordovician		
5	Corniferous	Dev	Ls	Por	20±					
6	Corniferous	Dev	Ls	Por	20±	MC				
7	Corniferous	Dev	Ls	Por	40±	AF	5x			
8	Corniferous	Dev, Sil	Ls	Por	40±	AF	1zz	Ordovician		
9	Corniferous	Dev, Sil	Ls	Por	25±	AF	7x	Ordovician		
10	Corniferous	Dev	Ls	Por	25±	A, D	8x	Devonian	2,190	
11	Big lime	Mis	Ls	Por	15	A	3	Devonian	1,962	16
12	Big lime	Mis	L	Cav	10-40	MC	10	Devonian		
13	Silurian		L	Cav	10±	MC	7x	Ordovician		
14	Corniferous	Dev	Ls	Por	20±	MC	4x	Ordovician		
15	Corniferous	Dev	Ls	Por	25±	S	1zz	Ordovician		
16	Corniferous	Dev	L	Por	20±	AF	2x	Devonian		
17	Weir	Mis	S	Por	35	D, A	9x	Ordovician	3,815	
18	Weir	Mis	S	Por	30	D	4x	Ordovician	3,900	
19	Weir	Mis	S	Por	60	D	1zz	Silurian		
20	Weir-Berea	Mis	S	Por	30	DF, A, S	15x	Devonian		
21	Berea	Mis	S	Por	20±	S	2x	Ordovician	4,975	17
22	Jett sand	Mis	Sand	20%	40	A	56	Trenton	4,020	18
23	Weir	Mis, Dev	S, H, Ls	Por	40± 20± 350	A	10	Devonian	1,780	
24	Maxon, Big lime			Por,						
25	Big Injun	Mis	S, Ls	Cav	15±	ML, MC, T	3x	Ordovician	3,706	
26	Corniferous	Dev	Ls	Por	18±	MC	4	Ordovician	855	19
27	Beaver-Sunny Brook	Mis, Ord	Ls	Por	12	S	2zz	Ordovician	1,921	
27	Blue sand	Sil	L	Cav	15±	T, MC, A	2zz	Silurian		
28	Barlowe & Bethel	Mis	Sand	15%	20	AF	17	Devonian	3,242	
29	Jett, Jackson, Barlowe, Bethel	Mis	Sand	15-20%	30	AF	14	Devonian	3,250	
30	Fuqua, Stray, Pottsville, Jett, Barlowe, Jones	Pen, Mis	S	18-20%	2-75	AN, AT, D	1,zzz	Ordovician		
31	Triplett, Jones	Pen, Mis	S	Por	30±	D, A	6x	Devonian		
32	Big lime	Mis	Ls	Por	20±	D	2x	Devonian		
33	Shallow sand Cornif, Deep sand	Mis, Dev	Ls	Por	15±	D, T, A, MC	1,zzz	Ordovician		
34	2d sand, Corniferous Amber oil sand	Mis, Dev, Sil, Ord	Ls	Por	10±	MC, T, D, N	1,zzz	Ordovician		
35	Trenton									
35	Salt sand, Maxon, Big lime, Big Injun, shale Cornif., Big 6	Pen, Mis, Dev, Sil	S, L, Ls, H	Por, Cav	15-550	A, D, MC, T, N, S	96	Silurian	3,643	
36	Salt sand, Maxon, Big lime, Big Injun, Dev shale	Pen, Mis, Dev	S, L, H	Por, Cav	10-800	A, AM, H, MC, D, T, S	36	Devonian	4,181	
37	Salt sand, Maxon, Big lime, Big Injun, Dev shale	Pen, Mis, Dev	S, L, H	Por, Cav	10-600	A, AF, D, T, MC, S	33	Devonian		
38	Salt sand, Maxon, Big Lime, Big Injun, Dev shale	Pen, Mis, Dev	S, L, H	Por, Cav	20-500	A, AM, H, MC, D, T, S	20	Ordovician	3,706	

¹⁶ New Oil Pools in Kentucky. Ky. Geol. Survey.¹⁷ Owens Bottling Co.¹⁸ This field put in vacuum during 1936.¹⁹ Jillson: Ky. Geol. Survey (1922) [6].

sippian to the middle Pennsylvanian age, most of the production coming from the Jett, Jones, Barlow and Bethel sands of the Chester series.

LIVERMORE POOL AND BATES KNOB

The year saw the complete development of the Livermore pool, in McLean County. This pool produced from the Bethel and Barlow

TABLE 1.—(Continued)

Line Number	Field, County	Age, Years to End of 1936	Area Proved, Acres				Total Oil Production, Bbl.
			Oil	Oil and Gas ^a	Gas	Total	To End of 1936
39	Boyd County and Ashland, <i>Boyd</i>	12			16,640	16,640	
40	Perry gas (Hazard), <i>Perry</i>	6			1,200	1,200	
41	Oneida—Burning Springs, <i>Clay</i>	11			7,000	7,000	
42	Burning Springs gas, <i>Clay</i>	27					
43	Indian Creek gas, <i>Knox</i>	7	0	0	1,200	1,200	
44	Artemus-Himyar gas, <i>Knox</i>	6	0	0	4,600 ^{EW} 5,000	5,000	0
45	Red Bird gas field, <i>Bell</i>	6	0	0	600	600	
46	Williamsburg oil and gas pool, <i>Whitley</i>	34		700		700	4,000
47	Big 6 gas, <i>Breathitt</i>	16			1,600	1,600	
48	Rothwell gas field, <i>Menifee</i>	35	0	0	15,360	15,360	
49	Powell gas, <i>Powell</i>	4					
50	Carlisle gas field, <i>Gallatin, Carroll</i>	4					
51	Swamp Br. gas, <i>Johnson</i>	9	3	0	3,000	3,003	Not marketed
52	Flat Gap gas, <i>Johnson</i>	16			10,880	10,880	
53	Win gas, <i>Johnson</i>	19			1,980	1,980	
54	Cain, <i>Lawrence</i>	7	0	0	550	550	0
55	Green-Taylor gas, <i>Green-Taylor</i>	(Field abandoned)					
56	Cumberland—Clinton, <i>Cumberland, Clinton</i>	42					2,xxx,xxx ⁹
57	Little Richland, <i>Knox</i>	33					
58	Ivyton, Licking and Mine Fk. gas, <i>Magoffin</i>	16			6,840	6,840	
59	Needmore gas field, <i>Owsley</i>	16			6,400	6,400	
60	Mortons Gap, <i>Hopkins</i>	14	50			50	
61	Buford, <i>Ohio</i>	7	346			346	1,414,400
62	Habit, <i>Daviess</i>	6	100			100	200,000
63	Lindsay Taylor pool, <i>Daviess</i>	7	15			15	22,577
64	Herbert, <i>Ohio</i>	16	350			350	408,370
65	Red Hill, <i>Daviess</i>	9	400			400	443,000
66	North Triplett gas field, <i>Rowan</i>	32 ¹⁰			1,200	1,200	
67	Bates Knob (New Pool—1936), <i>McClean</i>	1	350		120		53,624

⁹ Cumberland and Clinton Counties have produced over two million barrels of oil, but as oil has been shipped by water truck, pipe line, and railroad for over 40 years, it is impossible to obtain production figures. The old American well was drilled in Cumberland County over 90 years ago, and oil from it was used for medicinal purposes in this country and Europe.

¹⁰ Some eight or ten wells were drilled in Rowan County following 1904 and the development of Ragland oil field in adjoining Bath County. Some of these wells produced gas from the Corniferous lime and two still produce gas for local use.

sands, which were found at depths ranging from 1300 to 1400 ft. There were 163 wells drilled during the year in this pool, having initials of 40 to 450 bbl. The oil had a gravity of 34.5° Baumé. The Barlow sand, extending under the city limits of Livermore, caused a town-lot development that proved to be just another town-lot boom with the usual

TABLE 1.—(Continued)

Line Number	Total Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells								
	During 1935	During 1936	Daily Average during Nov. 1936	To End of 1936	During 1935	During 1936	Maximum Daily during 1936	Completed to End of 1936	During 1936		At End of 1936					
									Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas ^b	Producing Gas Only	Total Producing	
39				y	y	y		216	0	2x		2		214	1xx	
40				y	y ¹¹	y	y	6		2	2			6	2	
41				y	y	y		30	6		26			26	26	
42				y	y ¹²	y	y	5						5		
43				y	y	y		7	1	0					7	
44	0	0	0	y	y	y		19	1	0	12			19	7	
45					0	0	0	3	0	0	3			3	0	
46								30	0	0		25	0	5	5	
47				y	y	y		14	3	10	1			3	3	
48				y	0	0	0	8x							0	
49								2x	2							
50														2x		
51	0	0	0	y	y	y	y	22	0 ¹³	0	22	2	1	19	19	
52				y	y	y	y	2xx	0	2x	1xx				7x	
53				y ¹⁴	y	y	y	28		2x					6	
54	0	0		0	0	0	0	9			9			9	9	
55	185	159														
56																
57				y	y	y	y	104	0	2x				104	5x	
58																
59							2,000	48		1x				3x	3x	
60	500							5							Abandoned	
61	141,800	283,600	612					125	0	0					125	
62	29,200	x						11	1	1	0	11		2	12	
63	1,277	Abandoned						3		3		3			3	
64	19,760	18,700	51					131	2	4					129	
65	60,000	55,000	153					45	0	0					45	
66				15				17	9	0	10			10	10	
67	0	53,624	147	19		19	1,200,000	25	25	8					25	

¹¹ Production furnishes town of Hazard domestic.

¹² Gas production from this field is utilized only locally for domestic purposes.

¹³ During 1936 one well was deepened to the Big 6 horizon of Devonian Silurian age and developed 200,000 cu. ft. open flow.

¹⁴ This field is practically depleted.

¹⁵ Gas not being marketed; average well, 187,000 cu. ft. This production will possibly find domestic market in town of Morehead, 3 miles to the east, in which the Morehead State Normal School is located.

destructive results. In less than five months the pressure in the wells had declined from 250 lb. to 50 lb., and the well average dropped to 20 bbl. This pool produced 993,736 bbl. of oil during 1936.

Another development of note in McLean County was the discovery of Chester sand oil in the Bates Knob faulted anticline 6 miles southwest of the Livermore field. During the year 14 wells were completed in the Barlow and Bethel sands at depths ranging from 1550 to 1700 ft. The wells had an average initial production of 150 bbl. a day. This pool produced 53,624 bbl. during the year.

TABLE 1.—(Continued)

Line Number	Depth, Average in Feet		Oil Production Methods at End of 1936			Pressure, Lb. per Sq. In. ^s			Character of Oil, Approx. Average during 1936					Character of Gas, Approx. Average during 1936	
	Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells		Injection into Reservoir ^c	Initial	Average at End of		Gravity A.P.I. at 60° F.				Base ^e	B.t.u. per Cu. Ft.	Cal. Gasoline per M. Cu. Ft.
			Flowing	Pumping			1935	1936	Maximum	Minimum	Weighted Average	Sulphur Per Cent			
39	2,200±	1,650±				y	y	y							
40	2,700-3,300	2,200-2,900													
41	1,550-1,700	1,525-1,675				305									
42															
43	1,550	1,500													
44	1,110±-2,100±	1,080±-2,000±				310	310	310						1,180	0
45	3,500± 900± Oil	3,400± 850±													
46	1,750± Gas	1,700±				240							P		
47	1,750-1,900	1,725-1,875													
48	550- 700	500- 650													
49															
50	240- 350	225- 335				160		20							
51	1,800	1,425													
52	780-1,200	740-1,160													
53	700-1,100	670-1,070													
54	2,100-2,500	2,050-2,450													
55	1,670-1,760	1,650-1,740													
56															
57	200- 500														
58	1,100-1,400	1,050-1,350													
59															
60	900-1,200	850-1,150		0		317								1,085	1 Qt.
61	600	585		129					10 Points Vacuum	35.5		35.5			
62	930	910		10						35		55			
63	1,125	1,085													
64	750	670- 725		129				4	35		34				
65				45							34				
66	350	335				45									
67	400-1,700	340-1,670	2	23		360		340							

WORK IN OLD POOLS

There was very little new work done in the shallow areas of Hancock, Ohio and Daviess Counties, but several pressure wells were drilled in the old pools for repressuring with both gas and air. Most of this repressur-

TABLE 1.—(Continued)

Line Number	Producing Rock						Number of Dry and/ or Near-dry Holes to End of 1936	Deepest Zone Tested to End of 1936		Reference to Text ⁱ
	Name	Age ^f	Character ^g	Porosity ^h	Net Thickness, Average in Feet	Structure ⁱ		Name	Depth of Hole, Ft.	
39	Salt sand, Maxon, Black Shale, Cornifer- ous	Pen, Mis, Dev	S, H, SL	Por	50± 400± 150±	T	29	Ordovician	4,669	20
40	Salt sand, Big lime, Brown shale	Pen, Mis, Dev	S, L, H	Por, Cav	50± 500±	MC	11	Devonian	3,637	
41	Corniferous	Dev	Ls	Por	20±	A, MC	16	Devonian	2,284	
42	Corniferous	Dev	Ls	Por	25±	A, D	1x	Devonian		
43	Big lime	Mis	L	Cav	20	T	1	Mississippian	1,552	
44	Maxon, Brown shale Corniferous	Mis, Dev	S, H, Ls	Por	30± 175± 100±	A, AF, D	2	Devonian	2,225	
45	Big lime, Brown shale, Corniferous	Mis, Dev	L, H	Cav, Por	100± 175± 50±	MC	2	Devonian	3,725	
46	Salt sand, Big lime	Pen, Mis	S, L	Por, Cav	30± Oil 20± Gas	A	1x	Ordovician	3,350	21
47	Big 6	Sil	S	Por	25±	A	1x	Silurian		
48	Corniferous, Ragland sand	Dev	Ls	Por	40±	D	4x	Ordovician		
49	Corniferous	Dev	Ls	Por	20±	MC	1x			
50	Trenton	Ord	Ls	Por	15±	D	1x	Ordovician	967	
51	Maxon, Big lime, shale	Mis, Dev	S, L, H	Por, Cav	40± 350±	Depositional	0	Devonian	1,816	
52	Weir, Corniferous	Mis, Dev	S, Ls	Por	40±	D	2x	Ordovician	3,719	
53	Weir, Big 6	Mis, Sil	S, Ls	Por	30±	A	8	Devonian		
54	Corniferous	Dev	Ls	Por	18	MC	7	Devonian	11,983	
55	Sunnybrook-Trenton Salt sand	Ord	S, Ls	Por		A, D		Cambro. Ord.	1,934	
56	Weir, Bl. Shale, Cornif- erous, Salt sand,	Pen, Mis, Dev	S, H, L	Por, Cav	15± 40± 450±	D, A, MC, T, S	57	Ordovician	3,950	22
57	Maxon, Big lime, Big Injun									
58	Corniferous	Dev	Ls	Por	40±	MC	25	Devonian		
59	Salt sand, Caseyville	Pen, Mis	S, L	Por	20± 6±	AF		Mississippian	2,132	
60	Pottsville	Pen	Sand	15 Por	15	Channel		Mississippian	1,250	
61	Fuqua, Stray sand	Mis	S	18-20 %	20	A	10	Mississippian	1,350	23
62	Jones, Hardingsburg Salt sand	Mis	S	Por	40	AF	13	Mississippian	1,340	24
63	Jett to Barlowe	Mis	Sand to sandy Ls	12	5-30	T, A		Mississippian	950	
64	Jett	Mis	Sand	18 %	14	A	19	Mississippian	1,020	
65	Corniferous lime	Dev	Ls	Por	11	MC	7	Ordovician	1,501	25
66	Bethel lime, Pottsville	Pen, Mis	Sand, lime	12-25 %	20	Faulted anticline	8	Mississippian	1,906	
67	Barlowe, Bethel sand									

²⁰ New Oil Pools in Kentucky. Ky. Geol. Survey (1926) [6].²¹ Reference of footnote 19.²² Kentucky-West Virginia Gas Co.²³ Univ. of Kentucky Bull. 3.²⁴ Ky. Geol. Survey (1930) [6].²⁵ Ky. Geol. Survey (1922) [6].

ing was in areas where the Jett sand (Tar Springs) was the producing horizon. The results so far have been very profitable.

In the fields of the central, southern, and southeastern part of the state, in Allen, Barren, McCreary, Metcalf, Simpson, Warren, Wayne and Hart Counties, with only one exception, there was no new activity during the year. Only routine work was done in the developed areas, and very little, if any, exploratory drilling. The production in most of these fields comes from the Devonian limestones underlying the Black shale of that age.

In Wayne County, however, where the production has formerly been found in the "Beaver" sand of Mississippian age, lying immediately above the Devonian shale, three wells on being deepened have encountered large production from the lower "Sunnybrook" sand of Upper Ordovician age. This production comes from the same stratigraphic horizon as that found from time to time in Cumberland County to the west. In that section the wells have been "flashy," having a large flush production but declining rapidly to the economic in a short time. The new discovery in Wayne County is about nine miles southwest of Monticello, and to date three wells have been completed. The first was given a flush yield of approximately 5000 bbl. daily, but after several days production had declined to around 50 bbl., which it is reported to be doing now. Initial production in the other two wells was not as large. The development has created renewed interest in this old, almost abandoned area, and may have beneficial results in causing a revival of the field.

Gas

The development of eastern Kentucky's most important Devonian shale gas area in Floyd, Martin, Pike, Knott and Magoffin Counties was maintained at the same or increased rate during 1936. Over one hundred shale wells averaging 400,000 cu. ft. per well were drilled. The discovery of the new large Oriskany gas field in Kanawha County, West Virginia, 100 miles to the northeast, has caused no change in the situation in eastern Kentucky either in additional development or impairment of market demand.

In the northwestern Kentucky fields of Ohio, Hancock, Daviess, McLean, Henderson and Webster Counties, 72 new gas wells were completed during the year, with a combined initial open flow of 70,000,000 cu. ft. of gas. The producing sands range from middle Mississippian to middle Pennsylvanian in age. Most of the production comes from the Barlow, Jones and Jett sands of the Chester series.

In connection with the development of the Bates Knob oil field, southwest of Livermore, in McLean County, considerable gas has been

developed. This structure is a faulted anticline and has proved to be a large producer of gas from both the Chester sands and the Pottsville sand. One well in the Jett sand (Tar Springs) at 1220 ft. had an open flow of 21,000,000 cu. ft. Three wells on this structure had open flows of 13,000,000, 8,000,000 and 4,000,000 cu. ft., respectively, from the Pottsville sand, which was found at depths from 750 to 790 feet.

Oil and Gas Development in North Louisiana

BY BENJAMIN C. CRAFT,* MEMBER A.I.M.E.

A REVIEW of development in North Louisiana during 1936 centers around the Rodessa field, in Caddo Parish. Continued extension of the

TABLE 1.—Oil and Gas Production in North Louisiana

Line Number	Field, Parish	Age, Years to End of 1936	Area Proved, Acres				Total Oil Production, Bbl.
			Oil	Oil and Gas ^a	Gas	Total	To End of 1936
1	Caddo, Caddo ¹	33	32,500	0	15,040	47,540	149,243,405
2	Red River, Bull Bayou, De Soto, Red River.....	23	11,000	0	3,300	14,300	56,278,525
3	Lake Bisteneau, Bienville.....	21	0	0	600	600	
4	Elm Grove, Caddo, Bossier.....	21	320	0	14,600	14,920	3,193,625
5	Monroe, Morehouse, Ouachita, Union.....	21	0	0	123,340	123,340	
6	Bethamy ² , Waskam ² , Caddo.....	21	0	0	1,800	1,800	
7	Homer, Claiborne.....	18	0	3,024	0	3,024	66,399,875
8	Haynesville, Claiborne.....	16	0	7,480	0	7,480	66,626,015
9	Shongaloo, Webster.....	16	70	0	5,680	5,750	101,900
10	Bellevue, Bossier.....	16	1,360	0	160	1,520	11,637,300
11	Sligo, Bossier.....	15	20	0	4,400	4,420	20,005
12	Spring Hill, Sarepta, Bossier, Webster.....	15	570	0	1,120	1,690	1,386,575
13	Cotton Valley, Webster.....	15	3,900	0	2,700	6,600	14,860,430
14	Carterville, Bossier.....	13	720	0	2,720	3,440	1,450,150
15	Urania, Winn, Grant, LaSalle.....	12	3,700	0	0	3,700	21,250,495
16	Richland, Richland.....	11	0	0	49,280	49,280	
17	Pleasant Hill, Sabine, DeSoto.....	10	800	0	0	800	1,435,900
18	Zwolle, Sabine.....	9	64,000 ³	0	0	64,000 ³	12,911,140
19	Epps, East & West Carroll.....	9	0	0	1,200	1,200	
20	White Sulphur Springs, La Salle.....	9	80	0	0	80	12,290
21	Holly, DeSoto.....	7	80	0	0	80	857,440
22	Rodessa ⁴ , Caddo.....	7	5,518	0	3,100	8,618	20,485,305
23	Sugar Creek, Claiborne.....	6	0	0	2,800	2,800	
24	Clayton, Concordia.....	6	0	0	60	60	
25	Converse, Sabine.....	5	1,600	0	0	1,600	1,438,105
26	Sutherland, DeSoto.....	2	0	0	50	50	
27	Ruston, Lincoln.....	2	0	0	100	100	
	Total.....		126,238	10,504	232,050	368,792	429,588,480

^a Footnotes to column heads and explanation of symbols are given on page 291.

¹ Includes the following districts: Cedar Grove, Shreveport, Jeems Bayou, Trees City, Monterey, Harts Ferry, Ferry Lake, Mooring Port, Gilliam, Pine Island, Vivian, Dixie and Blanchard.

² Includes the part of each field in Louisiana and the Greenwood area.

³ Scattered production over 64,000 acres.

⁴ Louisiana side.

Manuscript received at the office of the Institute March 23, 1937.

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field into Cass County, Texas, and new completions on the northeast end of the field point to further development during 1937. The search for Glen Rose and Travis Peak production on the geophysical prospects resulted in the discovery of three new fields and the proving of new producing horizons in seven of the old fields.

During the year, 346 oil wells, 109 gas wells, and 78 dry holes were completed, as compared with 144 oil wells and 68 gas wells during 1935. The North Louisiana oil production was 26,771,145 bbl. as compared with 9,616,405 bbl. during 1935, an increase of 17,154,740 bbl. or 178 per cent.

NEW FIELDS

Arcadia.—A new gas-producing area was discovered in Bienville Parish when Lide, Greer and Marr's Davis Lumber Co. No. 1, sec. 12, 16 N., 5 W., Bienville Parish, tested 71,000,000 cu. ft. of wet gas from what is probably the equivalent of the Hill sand in Rodessa. The well

TABLE 1.—(Continued)

Line Number	Total Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
	During 1935	During 1936	Daily Average during Nov. 1936	To End of 1936	During 1935	During 1936	Maximum Daily during 1936	Completed to End of 1936	During 1936						
									Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas ^a	Producing Gas Only	Total Producing
1	2,481,445	2,381,065	6,550	135,106	1,947	1,643	6	3,838	23	0	2	1,164	0	48	1,212
2	514,715	501,460	1,365	62,553	1,385	1,324	4.5	1,249	3	9	10	167	0	34	201
3								10							
4	145,555	145,520	345	220,253	2,138	1,925	6	249	0	0	0	36	0	45	81
5				2,061,510	181,698	205,252	640	1,060	94	11	100	0	0	938	938
6				6,467	841	454	2	67	0	2	0	0	0	5	5
7	969,485	944,090	2,570	y	84	104	0.3	627	0	0	1	364	0	1	365
8	1,272,125	1,215,215	3,145	y	895	1,062	3	766	0	0	11	325	0	0	325
9	6,890	5,980	213	70,631	151	147	0.5	91	0	1	0	2	0	6	8
10	212,215	228,575	715	2,220	79	45	0.1	366	8	0	0	111	0	1	112
11		20,005	105	6	4,910	8,757	32	73	7	0	2	2	0	42	44
12	130,465	119,435	334	25,527	35	24	0.1	43	0	0	0	12	0	1	13
13	153,685	191,320	840	73,348	1,768	2,057	9	279	1	2	0	72	0	31	103
14	59,470	51,825	109	16,968	0	13	0.1	133	0	3	7	41	0	0	41
15	1,084,965	1,012,595	2,750	5	0	0	0	463	14	0	4	213	0	0	213
16				434,057	21,450	12,218	46	284	0	42	6	0	0	109	109
17	64,360	56,265	145					58	1	0	4	32	0	0	32
18	626,080	407,090	890					311	1	10	9	63	0	0	63
19				2,300	173	1,377	7	5	0	0	0	0	0	4	4
20	0	0	0					12	0	0	0	0	0	0	0
21	57,480	51,695	145					14	0	0	0	7	0	0	7
22	1,411,890	19,073,415	56,860	88,087	22,346	42,412	173	328	266	0	8	277	0	79	356
23				26,875	5,716	5,466	17	13	2	0	1	0	0	12	12
24				11	0	0	0	1	0	0	0	0	0	0	0
25	425,580	365,595	875					144	20	0	8	80	0	0	80
26				103		103	0.5	1	0	1	0			1	1
27	9,616,405	26,771,145	78,056	3,226,300	245,616	284,662	951.1	10,487	446	81	173	2,968		1,359	4,327

^a Included with Elm Grove.

was drilled to 6144 ft. but production was obtained from 5867 to 5883 ft. At the above rate of flow, the tubing pressure was 580 lb. and the closed-in pressure was reported as 2340.

Sibley.—J. P. Evans Crichton No. 1, sec. 35, 18 N., 9 W., Webster Parish, was the discovery well for the Sibley structure. The open-flow capacity was estimated at 80,000,000 cu. ft. per day. When tested through a 1/8-in. choke, the production was 113 bbl. of distillate and 10,000,000 cu. ft. of gas. The well was completed at 5589 ft. with production coming from the equivalent of the Hill sand.

TABLE 1.—(Continued)

Line Number	Depth, Average in Feet		Oil Production Methods at End of 1936					Character of Oil, Approx. Average during 1936					Character of Gas, Approx. Average during 1936	
	Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells				Injection into Reservoir ⁶	Gravity A.P.I. at 60° F.			Sulphur, Per Cent	Base ⁸		
			Flowing	Pumping	Gas-lift	Air-lift		Maximum	Minimum	Weighted Average				
1	2,067 ⁶	⁷	0	1,164	0	0	G	25-46	14-26	38	0.5	A, P	926	0.22 ¹²
2	823-2,648 3,577	787-2,600	0	167	0	0	G	41.5	40	41	0.25	P	y	0
3	2,018-2,553	1,993-2,544												
4	1,645 ⁸	1,621 ⁸	0	36	0	0		32	28	30	0.40	M	1,025	0.15 ¹³
5	2,205	2,145											1,017	0.13
6	1,823	1,718 ⁹											1,017	0.24
7	1,345-2,065	1,280-2,040	0	364	0	0	G	38	35	36	0.80	P	3,300	15 ¹⁴
8	2,805-4,844	2,790-4,559	0	325	0	0	G	35	32	33	0.40	P	1,100	1.50
9	2,680	2,665	0	2	0	0		30	28	29	0.35	M	971	0
10	370-1,035	360-1,010	0	111	0	0	G	20	19	19.2	0.80	A	970	0.34
	1,815	1,790												
11	¹⁰	¹⁰	2	0	0	0		40.4	40.2	40.3	y	P	972-1,057	0
														0.24
12	2,691	2,686	0	12	0	0		28	25	26	0.32	M	994-1,046	0.07
	3,063-3,165	3,059-3,143												0.33
13	2,547-4,652	2,532-4,350	1	71	0	0		30-52	29-48	31	0.25	M, P	866-1,004	1.5
														0.07
14	3,085-3,170	3,080-3,143	0	41	0	0		44	38	41	0.27	P	994-1,046	0.33
15	1,536	1,529	0	204	0	9		22	19	20.5	0.30	A		
16	2,447	2,349 ¹¹											1,060	0.34
17	3,237	3,175	0	32	0	0		42	38	40	0.30	P		
18	2,440	2,280	0	63	0	0		45.5	38	40	0.10	P		
19	2,344	2,336												
20	804	794											998	0
21	2,851	2,838	0	7	0	0		45	38	41	0.22	P		
22	5,676-6,014	5,560-5,891	269	4	4	0		47	42	45	0.10	P	1,060	0.50
														0.40
23	4,420	4,314											1,125	0.56
24	1,438	1,415											984	0
25	1,922-3,232	1,617-3,150	0	80	0	0		46	42	43	0.15	P		
26	2,841	2,818											y	y
27	5,297-6,570	5,270-y	272	2,683	4	9							y	y

⁶ Average depth of all wells completed.

⁷ Productive horizons and average depth to top of horizons are as follows: Nacatoch, 1000 ft.; Buckrange, 1823 ft.; Tokio, 2260 ft.; Trinity, 3647 ft.

⁸ Average bottoms of wells and tops of productive zones are as follows: 840-804 ft.; 1556-1548; 1915-1896 and 2496-2469 ft.

⁹ Also produces from contact of Upper and Lower Cretaceous, contact of Washita and Fredericksburg, Glen Rose and lower Glen Rose. The producing horizons are found at the following average depths: Nacatoch sand, 1000 ft.; Buckrange, 1950; 2300-ft. horizon, 2250-2350; Adams sand, 2600-2700; Augurs 2900-3000; 3100-3200 and 3300 ft. sands; 1st lower Glen Rose horizon, 4645 ft.; 2d Glen Rose horizon, 4697 ft.

¹⁰ Producing horizons: 845-883 ft., 1710-1745 ft., 2445-2480 ft., 2750-ft. sand, 4108-4275 ft.; and 5040-5200 ft.

¹¹ One well completed in Glen Rose at 2936 ft.

¹² Saturation in Blanchard area.

¹³ Gasoline content of gas from deep horizon; gas from other sands is dry.

¹⁴ Produces casinghead gas.

Claiborne Parish.—Completion of E. T. Oakes et al., Patton Estate No. 2, sec. 1, 20 N., 5 W., Claiborne Parish, resulted in the major discovery of the year. The discovery well was completed in the lower Glen Rose, flowing 192 bbl. of 38° A.P.I. gravity oil per day through a $1\frac{1}{32}$ -in. choke from a depth of 5379 feet.

NEW SANDS

The first oil production for the Sligo field, Bossier Parish, which formerly has produced gas from several horizons, was discovered by United Gas Public Service Company's Shannal F-1, sec. 26, 17 N., 12 W. The well was completed flowing 480 bbl. of 40° A.P.I. oil per day through a $\frac{5}{64}$ -in. choke with 300 lb. pressure in the tubing and 800 lb. on the casing. Production is from the Lower Glen Rose at 5201 feet.

First production from the Travis Peak below the Glen Rose was discovered by Lide and Greer's Simmie Gardner No. 1, sec. 10, 17 N.,

TABLE 1.—(Continued)

Line Number	Producing Rock						Deepest Zone Tested to End of 1936	
	Name	Age ¹	Character ²	Porosity ³	Net Thickness, Average in Feet	Structure ⁴	Number of Dry and/or New Holes to End of 1936 ⁵	Depth of Hole, Ft.
1	Basal CreU Glen Rose, Nacatoch, "Chalk Rock"	CreU, CreL	C, S	Por	16	A	902 L. Trinity	6,351
2	Ozan, Tokio	CreU, CreL	S	Por	19	AF	309 Glen Rose	6,141
3	Nacatoch, Ozan, Tokio	CreU	S	Por	35	D	11 CreL	3,002
4	"Monroe Gas Rock"	CreU	S	Por	8	A	42 CreL	5,382
5	Nacatoch, Buckrange	CreU	LS	23	50	A	101 Glen Rose	4,155
6	Nacatoch, Buckrange ¹⁵	CreU, CreL	S, L	Por	120	A	53 Glen Rose	3,575
7	Buckrange, Glen Rose	CreU	S	Por	63	DF	196 Glen Rose	4,504
8	Buckrange	CreU, CreL	S	Por	25	A	61 Glen Rose	5,092
9	Nacatoch, Buckrange, L. Glen Rose	CreU	S	Por	12	A	26 Glen Rose	4,750
10	Nacatoch, Buckrange, Tokio, Fredericksburg, Glen Rose	CreU, CreL	SL	Por	8	DF	109 L. Trinity	6,137
11	Buckrange, Tokio	CreU	S	Por	11	A	19 Glen Rose	5,120
12	Buckrange, Travis Peak, Glen Rose	CreU, CreL	SAS	27-24	11	A	26 Travis Peak	8,556
13	Buckrange, Tokio	CreU	S	Por	16	A	49 Trinity	3,476
14	Cane River-Wilcox Contact	Eoc	S	Por	9	MU	152 Tokio	6,463
15	Tokio "Monroe Gas Rock," Glen Rose	CreU, CreL	S, LS	Por	76	A	39 L. Trinity?	8,943 Dr
16	Washita	CreL	C, S	Por	16	A	25 Glen Rose	5,063
17	Saratoga, Marlbrook, Anona, Ozan	CreU	S	Por	8	AF	414 Glen Rose	7,155
18	"Monroe Gas Rock"	CreU	LS	Por	8	D	10 Glen Rose ¹⁷	3,142
19	Basal Jackson	Eoc	S	Por	9	NF	8 Wilcox	2,435
20	Eagle Ford	CreU	S	Por	11	N	27 Fredericksburg	3,373
21	Lower Glen Rose	CreL	LS	Por	25	AF	18 L. Trinity	6,715
22	Glen Rose, Travis Peak	CreL	L	Por	20	A	14 Travis Peak?	8,616
23	Basal Jackson	Eoc	S	Por	25	N	6 Wilcox	3,705
24	Nacatoch, Saratoga, Anona, Ozan, Washita	CreU, CreL	M, C, S	Por	10	D	65 Glen Rose	4,433
25	Glen Rose, Travis Peak	CreL	S	Por	25	AL	0	2,841
26							0	6,575
27							2,689	

¹⁵ Goes also under name of Oakes sand or Haynesville sand.¹⁶ Dry holes drilled in fields and those drilled in defining producing limits.¹⁷ Abandoned in igneous rock.

4 W., Lincoln Parish, which was completed flowing 67,000,000 cu. ft. of wet gas per day from a total depth of 6576 ft. This horizon has also proved productive at Cotton Valley and Blanchard.

The important discoveries in the old fields are listed in Table 2.

TABLE 2.—*Summary of Drilling Operations in North Louisiana*

Important Wildcats Drilled in 1936						
	Parish, <i>Field</i>	Location			Total Depth, Ft.	Surface Formation
		Sec.	Twp.	Rge.		
		Survey	Lat.	Long.		
1	Bossier, <i>Sligo</i>	17	17 N.	11 W.	5199	Pleistocene
2	Claiborne, <i>Sugar Creek</i>	7	19 N.	5 W.	5311	Claiborne
3	Caddo, <i>Rodessa</i>	8	23 N.	15 W.	6107	Claiborne
4	Caddo, <i>Blanchard</i>	16	18 N.	16 W.	5911	Wilcox
5	Webster, <i>Cotton Valley</i>	23	21 N.	10 W.	5556	Claiborne
6	Bossier, <i>Sligo</i>	26	17 N.	12 W.	5201	Pleistocene
7	Bienville, <i>Lake Bisteneau</i>	15	16 N.	10 W.	5236	Pleistocene
8	Lincoln, <i>Ruston</i>	10	17 N.	4 W.	6575	Pleistocene

Important Wildcats Drilled in 1936								
	Deepest Horizon Tested	Drilled by	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
			Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
1	L. Glen Rose	Producers O. & G. Co.	190	12	y	2110	2150	N.S. 5044-5199 ft.
2	Travis Peak	Sugar Creek Syn.	23	5	y	2310	y	N.S. 5407-5311 ft.
3	Glen Rose-Hill	Blackwell O. & G. Co.	105	y	3/8	190	1900	N.S. y
4	Travis Peak	United Gas & Pyramid	Wet Gas	3	O.T.	2260		N.S. y
5	Travis Peak	Ohio Oil Co.	480	5	3/8	2000	1750	N.S. 5536-5552 ft.
6	L. Glen Rose	United Gas	480		5/8	800	300	First Oil Prod. Sligo
7	L. Glen Rose	De Soto Oil & Gas Co.	Wet Gas	15	O.T.	y	y	N.S. 5190-5235 ft.
8	Travis Peak	Lide & Greer	Wet Gas	67	y	2900	y	N.S. y

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1936.....	59	26
Number of oil wells completed during 1936.....	345	1
Number of gas wells completed during 1936.....	106	2
Number of dry holes completed during 1936.....	33	45

ACKNOWLEDGMENTS

For information furnished in the preparation of this summary, the writer wishes to thank Dr. H. V. Howe, Director of the School of Geology, Louisiana State University; Mr. B. Peters, Chief Scout, and Mr. E. B. Hutson, Chief Geologist, of the Standard Oil Company of Louisiana.

Oil and Gas Development in South Louisiana

BY BENJAMIN C. CRAFT,* MEMBER A.I.M.E.

OPERATIONS on the Louisiana Gulf Coast during 1936 resulted in the discovery of five new fields and the proving of flank production or new sands on 12 of the older fields. This district gained the rank as the outstanding deep-drilling region of the world. At the close of the year, 10 wells had been drilled beyond 10,000 ft. One of the most important

TABLE 1.—*Oil and Gas Production in South Louisiana*

Line Number	Field, Parish	Age, Years to End of 1936	Area Proved, Acres				Total Oil Production, Bbl.
			Oil	Oil and Gas ^a	Gas	Total	To End of 1936
1	Jennings, Acadia.....	36	235	0	0	235	52,303,708
2	Anse La Butte, St. Martin.....	35	25	0	0	25	821,610
3	Welsh, Jefferson Davis.....	34	50	0	0	50	608,435
4	Vinton, Calcasieu.....	27	265	0	0	265	42,072,307
5	Edgerly, Calcasieu.....	25	215	0	0	215	8,377,175
6	Pine Prairie, Evangeline.....	25	10	0	0	10	20,000
7	Houma, Terrebonne.....	25	0	0	720	720	
8	Bayou Bouillon, St. Martin.....	21	20	0	0	20	384,483
9	New Iberia, Iberia.....	20	50	0	0	50	2,493,139
10	Lookport, Calcasieu.....	13	270	0	0	270	13,662,285
11	Starks, Calcasieu.....	12	50	0	0	50	2,211,363
12	Sulphur, Calcasieu.....	11	50	0	0	50	9,870,106
13	Sweet Lake, Cameron.....	11	250	0	0	250	3,157,909
14	Fausse Point, Iberia.....	10	10	0	0	10	31,726
15	Hackberry, Cameron.....	9	80	0	0	80	2,449,294
16	East Hackberry, Cameron.....	9	140	0	0	140	15,444,837
17	Sorrento, Ascension.....	9	20	0	0	20	719,695
18	White Castle, Iberville.....	8	50	0	0	50	1,776,240
19	Port Barre, St. Landry.....	8	75	0	0	75	6,156,932
20	Dog Lake, Terrebonne.....	8	20	0	0	20	471,658
21	Bayou Blue, Iberville.....	8	30	0	0	30	61,837
22	Black Bayou, Cameron.....	8	30	0	0	30	3,384,190
23	Lake Pelt, Terrebonne.....	8	20	0	0	20	254,958
24	Lake Barre, Terrebonne.....	8	100	0	0	100	13,728,488
25	Caillon Island, Terrebonne.....	7	100	0	0	100	10,556,425
26	Cameron Meadows, Cameron.....	6	40	0	0	40	3,442,297
27	Choctaw, Iberville.....	6	20	0	0	20	1,288,890
28	Lake Washington, Plaquemine.....	6	200	0	0	200	1,637,353
29	Leeville, Lafourche.....	6	210	0	0	210	14,473,281
30	Iowa, Calcasieu-Jefferson Davis.....	6	0	1,000	0	1,000	23,069,594
31	Darrow, Ascension.....	5	75	0	0	75	806,823

^a Footnotes for column heads and explanation of symbols are given on page 291.

Manuscript received at the office of the Institute March 23, 1937.

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deep tests is Continental Oil Company's Hebert No. 1, sec. 20, 12 S., 3 E, Vermilion Parish, which was drilled to 12,216 ft. and which holds the casing depth record with 5 in. cemented at 11,795 ft. Early tests have indicated that the well will be completed as a wet gasser.

During the year the introduction of retarded or slow-setting cements has resulted in satisfactory cementing operations in the deep and high-temperature areas.

The total oil production for South Louisiana during 1936 was 52,968,-632 bbl., as compared with 40,874,084 bbl. during 1935, an increase of 29.5 per cent. There were 262 oil and gas wells and 135 dry holes completed during 1936 as compared with 222 oil and gas wells and 128 dry holes during the previous period.

Despite a record year in 1936, the year of 1937 looms as an even greater one from a development standpoint, as drilling will be continued on a great many of the geophysical prospects and in new fields.

NEW FIELDS

Bayou Mallet.—The Bayou Mallet field was discovered by the Superior Oil Producing Company's and Woodley Petroleum Company's G. Bradley

TABLE 1.—(Continued)

Line Number	Total Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
	During 1935	During 1936	Daily Average during Nov. 1936	To End of 1936	During 1935	During 1936	Maximum Daily during 1936	Completed to End of 1936	During 1936		At End of 1936				
									Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas ^a	Producing Gas Only	Total Producing
1	668,054	806,446	2,696					537	18	0	0	52			52
2	17,798	19,700	53					35	0	0	0	4			4
3	15,638	11,962	27					67	0	0	3	14			14
4	912,959	652,347	1,562					441	3	4	8	73			73
5	85,511	69,081	189					177	0	1	5	14			14
6	0	0	0					4							
7	0	0	0					10							
8	0	11,589	0					11	1	0	0	1			1
9	583,947	1,773,125	12,762					25	16	0	0	19			19
10	651,119	473,422	1,631					82	1	3	4	21			21
11	193,397	183,134	625					29	2	0	1	19			19
12	945,935	1,760,376	4,963					96	17	0	2	67			67
13	407,726	351,984	915					9	0	0	0	6			6
14	0	0	0					4							
15	164,185	189,620	937					58	4	0	3	22			22
16	2,425,928	2,969,047	8,771					121	5	7	7	47			47
17	47,397	139,071	273					12	3	0	5	2			2
18	208,988	332,588	1,750					9	2	0	1	8			8
19	1,316,489	836,411	1,874					46	4	0	3	29			29
20	35,037	229,308	865					3	1	0	0	2			2
21	0	0	0					6							
22	568,320	1,086,952	3,020					26	7	0	3	18			18
23	35,133	60,903	132					4	1	0	1	1			1
24	2,833,396	2,534,433	5,650					41	4	0	3	22			22
25	3,325,211	5,519,712	16,913					26	13	0	0	24			24
26	1,056,100	1,829,798	4,411					34	14	0	3	29			29
27	275,255	351,516	992					10	0	0	0	7			7
28	501,207	432,009	1,153					16	0	0	1	11			11
29	4,820,093	4,596,027	14,241					109	21	0	8	86			86
30	7,346,529	6,568,936	17,400	9,343	4,599	4,556	14.6	70	4	8	4		50		50
31	264,987	525,997	1,700					9	3	0	2	4			4

TABLE 1.—(Continued)

Line Number	Depth, Average in Feet		Oil Production Methods at End of 1936					Character of Oil, Approx. Average during 1936					Character of Gas, Approx. Average during 1936		
	Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells				Injection into Reservoir	Gravity A.P.I. at 60° F.				Sulphur Per Cent	Base	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.
			Flowing	Pumping	Gas-lift	Air-lift		Maximum	Minimum	Weighted Average					
1	1,944	1,833 ¹	5	43	4		26-34.5	21-34.5	28	0.17	A				
2	1,506	1,351 ²		4			24	22	23	0.37	A				
3	1,158	1,148		14			22.6	22	22.3	0.15	A				
4	2,752	2,685 ³		73			32	20	29.4	0.30	A				
5	3,145	3,107 ⁴		14			22	19	20	0.18	A				
6	1,269	1,200													
7	2,469	2,448													
8	3,050	2,838 ⁵		1											
9	2,458	2,398 ⁶	15	4			24.9	24.9	24.9	0.26	A				
10	4,558	4,537 ⁷	9	9		3	41	23	33	0.12	A				
11	2,272	2,224 ⁸	3	16			32	18	25	0.30	A				
12	4,160	4,136 ⁹	16	35		13	36	19	26	0.31	A				
13	6,284	6,262 ¹⁰	4	2			32	29	28.5	0.12	A				
14	1,170	1,137													
15	3,331	3,296 ¹¹	2	20			32	19	20	0.37	A				
16	3,700	3,668 ¹²	18	29			32	20	28	0.44	A				
17	1,639-4,351	1,624-4,338		2			31	26	28	0.38	A				
18	5,188-5,836	5,170-5,700 ¹³	4	1	3		26.5	24.2	25	0.36	A				
19	3,407	3,368 ¹⁴		29			33.7	25	27	0.33	A				
20	1,068-7,125	1,056-7,101	2				38.5	38.5	38.5	0.22	A				
21	2,319	2,262 ¹⁵													
22	4,535	4,446 ¹⁶	10	4	4		23.8	18	21	0.11	A				
23	1,373-6,270	1,274-6,248		1			34.3	34.3	34.3	0.55	A				
24	3,836	3,777 ¹⁷	16	3	3		35.5	33	34	0.32	A				
25	4,555	4,510 ¹⁸	24				34	32	33	0.26	A				
26	4,113	4,080 ¹⁹	12	17			41	27	37	1.0	A				
27	3,107	3,052 ²⁰	3	4			29.6	26.4	28.2	0.15	A				
28	1,154	1,135	11				19	18	18.5	0.73	A				
29	3,729	3,660 ²¹	21	58		7	29.2	22.9	26	0.40	A				
30	6,941	6,920 ²²	49		1		49.7	25.4	41	0.37	M	1,102	0.50		
31	²³	²³	3	1			41.6	34.1	37	0.12	A				

¹ Production obtained from following zones: 1515-2075 ft.; 3915-4330 ft.; 5480-5530 ft.; 6360-6375 ft.; 7300-7392 ft.; 7525-7545 ft.; 7683-7803 ft.; and 8600-8760 ft.

² Production obtained from following zones: 400-760 ft.; 1380-1535 ft.; and 1645-1890 ft.

³ Production obtained from following zones: 1100-1170 ft.; 1510-2150 ft.; 2050-2440 ft.; 2600-2800 ft.; 2915-3272 ft.; and 3395-3665 ft.

⁴ Production obtained from following horizons: 1060-1558 ft.; 2314-2355 ft.; 2655-2795 ft.; 2890-2920 ft.; 3095-3205 ft.; 3100-3264 ft.; 3405-3650 ft.; 3680-3740 ft.; 3910-4055 ft.

⁵ Production obtained from following horizons: 410-450 ft.; 3025-3210 ft.; 3235-3360 ft.; and 4284-4341 ft.

⁶ Producing zones: 1003-1070 ft.; 1665-1710 ft.; 2690-2855 ft.; 3805-3828 ft.; 4476-4500 ft.; 4592 ft.; 4650-4737 ft.; 5385-5401 ft.

⁷ Producing zones: 1000-1095 ft.; 2960-3237; 3385-3400; 3620-3875; 4315-4435; 4705-4924; 5100-5665; 5970-5985; and 6445-6623 ft.; and 6687-6737 ft.

⁸ Producing zones: 535-570 ft.; 746-910; 1205-1240 C.R.; 1080-1278 Sd.; 2300-2315 ft.; 3000-3020; 3400-3420; 3690-3721; 4175-4288; 4436-4481; 4759-4795 ft.

⁹ Producing zones: 2760-2950; 3150-3575; 3985-4200; 4300-4525; 4775-5175; and 5325-5700 ft.

¹⁰ Producing zones: 5170-5195; 5632-5718; 5900-5925; 6795-6815; and 7335-7387 ft.

¹¹ Producing zones: 3010-3400; 3810-3975; and 4275-4350 ft.

¹² Producing zones: 2610-3100; 3900-4015; 5990-6140; and 7232-7242 ft.

¹³ Producing zones: 5170-5188; 5700-6042; 6546-6559; 8894-8902; and 8925-8942 ft.

¹⁴ Producing zones: 3150-3200; 3320-3420; 3542-3568; and 3710-3717; 4367-4883 ft.

¹⁵ Producing zones: 1710-1735; 1900-2300; and 3575-3590 ft.

¹⁶ Producing zones: 965-980; 4380-4520; 5080-5220; and 6615-6630 ft.

¹⁷ Production from sands between 3650 and 4080 ft.

¹⁸ Producing zones: 3206-3243; 3965-4006; 5980-6030; and 6829-6842 ft.

¹⁹ Producing zones: 3310-3375; 3510-3580; 3770-3850; 3904-4100; 4243-4259; 4325-4410; and 5263-5273 ft.

²⁰ Producing zones: 2030-2050; 2410-2560; 2880-2900; 4100-4400; 4515-4581; and 5413-5473 ft.

²¹ Oil and/or gas produced from sands found at the following average depths: 2800-3000; 3300-3560, 3670, 3760, 3837, 4200, 4400, and 4980-5047 ft.

²² Production obtained from sands found at the following average depths: 4515, 5135, 5585, 6525, 6935. Most wells have been deepened to or completed in the zone of 6935 ft.

²³ Producing zones: 4008-4035; 4820-4827; 5489-5513; 5669-5686 ft.; and 5822-5836 ft.

No. 1, sec. 51, 7 S., 1 E., Acadia Parish. On the first 24-hr. gauge, the well made 325 bbl. of 28° A.P.I. oil per day through a $\frac{3}{16}$ -in. choke, with a 500-lb. tubing pressure from *Heterostegina* sands found from 6385 to 6397 ft. Earlier in the year, the same operators completed Adam Smith No. 1, sec. 14, 7 S., 1 E., as a wet gas well. The initial production was 3 million feet of gas and 20 bbl. of distillate per day through a $\frac{7}{32}$ -in. choke with a 2375-lb. tubing pressure. The well was plugged back from 8387 ft. and completed in the *Marginulina* sand at 7198 feet.

Charenton.—Completion of a producing well by Mike Hogg et al. opened up the second new field on the Louisiana Gulf Coast. The discovery well, Lawes Realty Company No. 1, sec. 30, 13 S., 10 E., St. Mary Parish, was completed flowing 515 bbl. of 35° A.P.I. oil per day through

TABLE 1.—(Continued)

Line Number	Producing Rock						Deepest Zone Tested to End of 1936		
	Name	Age ^f	Character ^g	Porosity ^h	Net Thickness, Average in Feet	Structure ⁱ	Number of Dry and/or Near-dry Holes to End of 1936	Name	Depth of Hole, Feet
1	"Fleming" Marginulina	Mio	S	Por	55	DS	112	Vicksburg	8,903
2	Citronelle "Fleming" Jack	Pli, Mio, Eoc	S	Por	35	DS	79	Jackson	1,500 ²⁸
3	Pli-Mio contact	Pli, Mio	S	Por	8	D	43	Vicksburg	6,017
4	PliL, "Fleming" Discorbis, Marginulina	Pli, Mio	S	Por	90	DS	203	Jackson	6,553
5	PliL	Pli	S	Por	130	DS	89	Jackson	8,414
6	"Fleming"	Mio	S	Por	30	DS	31	"Fleming"	5,112
7	Upper Marine Mio	Mio	S	Por	10	D	13	Mio	5,645
8	"Fleming"	Mio	S	Por	28	DS	43	Vicksburg	3,910 ²⁹
9	PliL, "Fleming"	Pli, Mio	S	Por	46	DS	43	MioL	7,934
10	"Fleming" Heterostegina	Mio	S	Por	100	D	18	Marginulina	7,902
11	PliL cap rock "Fleming" MioL	Pli, Mio	S	Por	40	DS	58	Jackson ³⁰	7,207
12	"Fleming" Heterostegina	Mio	S	Por	120	DS	40	Mio	9,250 ³¹
13	"Fleming"	Mio	S	Por	40	DS	7	Mio	8,070
14	"Fleming"	Mio	S	Por	7	DS	18	"Fleming"	5,119
15	"Fleming"	Mio	S	Por	35	DS	111	Jackson ³⁰	3,424 ³²
16	"Fleming"	Mio	S	Por	65	DS	72	Claiborne	6,963 ³³
17	Cap rock, Vicksburg	z, Olig	A, S	Por	45	DS	26	Vicksburg	5,725 ³⁴
18	"Fleming"	Mio	S	Por	30	DS	5	"Fleming"	8,942
19	Marginulina	Mio	S	Por	35	DS	29	Heterostegina	4,883
20	PliL	Plio	S	Por	12	DS	15	MioU	7,128
21	"Fleming"	Mio	S	Por	20	DS	11	"Fleming"	6,103
22	Cap rock MioU Heterostegina	z, Mio	L, S	Por	120	DS	24 ³⁵	Marginulina	6,200 ³⁶
23	Upper Marine Mio	Mio	S	Por	55	DS	9	MioU	7,039
24	Upper Marine Mio	Mio	S	Por	75	DS	16	MioU	8,063 ^{Dr.}
25	Upper Marine Mio	Mio	S	Por	90	DS	14	MioU	6,017
26	"Fleming"	Mio	S	Por	40	DS	7	MioU	9,331
27	"Fleming"	Mio	S	Por	40	DS	16 ³⁷	"Fleming"	6,290
28	Cap rock, Super Cap Sand	z, Plio	L, S	Por	26	DS	30	Mio	5,860 ³⁸
29	Upper Marine Mio	Mio	S	Por	120	DS	20	MioU	7,300 ³¹
30	"Fleming" Heterostegina Marginulina	Mio	S	Por	53	D	10	Vicksburg	9,161
31	Upper Marine Mio	Mio	S	Por	34	DS	15	MioU	6,901

²⁸ Deepest well abandoned at 6204 ft. in the Miocene.²⁹ Deepest well abandoned at 6471 ft. in lower Miocene.³⁰ Abandoned in heaving shale.³¹ Abandoned in salt.³² Deepest well abandoned at 7834 ft.³³ Deepest well abandoned at 8384 ft.³⁴ Deepest well abandoned at 6565 ft.³⁵ Includes seven sulphur tests.³⁶ Deepest test abandoned at 6905 ft.³⁷ Includes eight sulphur tests.³⁸ Abandoned in salt at 6179 ft.

Dr., drilling.

a $\frac{5}{16}$ -in. choke with a tubing pressure of 775 lb., producing from Miocene sand at 7210 feet.

South Jennings.—In September 1936, Stanolind Oil and Gas Co. completed its Calcasieu National Bank No. 1, sec. 15, 10 S., 3 W., Jefferson Davis Parish, for an initial production of 120 bbl. of distillate and 3 million cubic feet of gas per day through a $\frac{3}{16}$ -in. choke with tubing pressure of 3200 lb. The well was plugged back from 9944 ft. to 8900 ft. and is producing from lower Miocene sand found from 8634 to 8648 feet.

Cankton.—Superior Oil Producing Co. developed Miocene production in its Savoie No. 1, sec. 26, 8 S., 3 E., St. Landry Parish. The well was drilled to 9428 ft. into the Frio, but failing to find deeper sands was plugged back and completed through perforations from 5316 to 5323 ft. The initial production was 65 bbl. per day through a $1\frac{1}{4}$ -in. choke with a tubing pressure of 2100 lb. and a casing pressure of 2150.

Valentine.—Completion in December by Pan-American Production Co. and Barnsdall Oil Co. of a producing well at Valentine, Lafourche Parish, opened up the fifth and most important new field. The discovery well, Harang No. 1, sec. 7, 17 S., 20 E., was completed flowing 480 bbl. of 34° A.P.I. oil per day through a $\frac{1}{4}$ -in. choke with a tubing pressure of 2100 lb. and a casing pressure of 2150 lb. Production is from Shoal River sand found from 6930 to 6950 ft. Three previous tests drilled on the structure were dry holes.

TABLE 1.—(Continued)

Line Number	Field, Parish	Age, Years to End of 1936	Area Proved, Acres				Total Oil Production, Bbl.
			Oil	Oil and Gas ^a	Gas	Total	To End of 1936
32	Gueydan, Vermilion	5	50	0	0	50	632,034
33	Bosco, Acadia, St. Landry	3	1,250	0	0	1,250	12,011,208
34	Lake Hermitage, Plaquemines	3	25	0	0	25	94,222
35	Roanoke, Jefferson Dams	3	500	0	0	500	4,118,663
36	Four Isle, Terrebonne	3	20	0	0	20	90,452
37	Gillis, Calcasieu	3	400	0	0	400	7,822,034
38	Lafitte, Jefferson	2	100	0	0	100	3,369,398
39	Tepetate, Acadia	2	500	0	0	500	1,604,649
40	Bunkie, Rapides	2	0	50	0	50	174,074
41	St. Martinville, St. Martin	2	0	50	0	50	329,687
42	Jeanerette, St. Mary	2	150	0	0	150	996,336
43	Garden Island Bay, Plaquemines	2	40	0	0	40	363,189
44	Charenton, Lafourche	1	10	0	0	10	16,709
45	Big Lake, Cameron	1	10	0	0	10	1,853
46	Bayou Mallet, Acadia	1	60	0	10	70	55,431
	South Louisiana		5,825	1,100	730	7,655	267,363,054

TABLE 1.—(Continued)

Line Number	Total Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
	During 1935	During 1936	Daily Average during Nov. 1936	To End of 1936	During 1935	During 1936	Maximum Daily during 1936	Completed to End of 1936	During 1936		At End of 1936				
									Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas	Producing Gas Only	Total Producing
32	82,747	60,026	146					5	0	0	1	3			3
33	6,371,715	4,577,615	10,252	4,800		4,800	21	69	0	0	7	58			58
34	70,853	22,964	59					3	2	0	0	3			3
35	1,619,562	2,260,365	5,649					27	12	0	3	23			23
36	59,020	11,018	19					2	0	0	0	1			1
37	2,094,750	5,678,922	16,986					57	23	0	0	57			57
38	644,944	2,724,454	9,646					8	5	0	0	8			8
39	131,764	1,472,885	5,388					40	35	0	2	38			38
40	8,919	165,155	337	1,936	111	1,825	6.3	5	4	0	0	5			5
41	28,352	301,335	698	73	21	53	0.3	3	2	0	2	1			1
42	2,814	993,522	4,540					11	11	0	0	11			11
43	52,305	310,884	216					4	3	0	2	3			3
44	0	16,709	0					1	1	0	1	0			0
45	0	1,853	5	81		81	0.7	1	1	0	0	1			1
46	0	55,431	236	259		259	1.5	4	4	0	0	4			4
	40,874,084	52,968,632	159,682	16,492	4,731	11,574	44.4	2,367	247	23	85	818	50		868

Line Number	Depth, Average in Feet		Oil Production Methods at End of 1936					Character of Oil, Approx. Average during 1936					Character of Gas, Approx. Average during 1936	
	Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells				Injection into Reservoir ^e	Gravity A.P.I. at 60° F.						
			Flow- ing	Pump- ing	Gas- lift	Air- lift		Maximum	Minimum	Weighted Average	Sulphur Per Cent	Base ^c		
32	3,972	3,924 ²⁴	2	1			G	27.5	27.1	27.3	0.12	A		
33	35	35	29					45.6	36	38.5	0.17	M		
34	36	36		3		29		32.1	32.1	32.1	0.06	A		
35	8,477	8,454 ²⁷	21	2				38.4	37	38	0.10	M		
36	5,642	5,512	1					44.5	44.3	44.4	0.18	M		
37	39	39	53			4	G	34.1	34.1	34.1	0.68	A		
38	40	40	8					35	35	35	0.19	A		
39	8,315	8,275	38					44.5	32	37	0.34	M		
40	5,710	5,704	5					53.9	53.9	53.9	0.30	A	1,146	0.75
41	5,582	5,557	1					32	32	32	0.21	A	1,019	0.03
42	41	41	11					40.7	40.7	40.7	0.31	M		
43	42	42	1	2				37.2	37.2	37.2	0.25	A		
44	7,185	7,206	0					36	35.5	36	y	M		
45	7,944	7,966	1					55	55	55	y	P	y	Wet
46	6,385	6,390	4					36.7	27.9	30	y	M	y	y
	6,996	7,000												
	7,140	7,180	398	398	48	24								

²⁴ Producing zones: 3450-3555; 3890-4300; and 4820-4850 ft.²⁵ Producing zones: 7760-7830; 8050-8090; 8420-8500; 8620-8700; 8750-8800; 9004-9024; and 9018-9028 ft.²⁶ Producing zones: 3176-3191; 4257-4269; and 4640-4646 ft.²⁷ Producing zones: 7796-7918; 8660-8682; 8814-8830; and 9314-9345 ft.²⁸ Producing zones: 5156-5180; 5258-5272; 6413-6419; 6710-6767; 7005-7085; 7368-7377; and 9242-9246 ft.⁴⁰ Producing zones: 9396-9440; 9555-9575; and 9912-9968 ft.⁴¹ Producing zones: 6630-6660; 6725-6735; 7010-7055; and 7478-7498 ft.⁴² Producing zones: 4450-4480; 4601-4616; 4885-4895; and 4915-4930 ft.

OTHER DEVELOPMENTS

The presence of a salt dome in the Lake Mongouloi area was proved when the Texas Company Lake Mongouloi No. 1, sec. 10, 9 S., 9 E., was drilled into salt at 7540 feet.

The Shell Petroleum Corporation proved the Hester prospect when its Colonial Sugars No. 1, sec. 5, 12 S., 5 E., was completed in salt at 7522 feet.

New sands were found at Darrow, Ascension Parish; Bayou Mallet, Acadia Parish; Gillis, Calcasieu Parish; Caillou Island, Terrebonne Parish; Jeanerette, St. Mary Parish; Leeville, Lafourche Parish; Jennings, Acadia Parish; New Iberia, Iberia Parish; Lake Hermitage, Plaquemines Parish; St. Martinville, St. Martin Parish; Port Barre, St. Landry Parish; Lafitte, Jefferson Parish.

The discovery wells of the new sands are listed in Table 2.

ACKNOWLEDGMENTS

For information furnished in the preparation of this summary, the writer wishes to thank Dr. H. V. Howe, Director of the School of Geology, Louisiana State University; Mr. R. M. Grigsby and Mr. G. O. Grigsby, of the Stanolind Oil and Gas Co.; Mr. D. Goodwill, of the Louisiana Department of Conservation; Mr. H. Eversberg, of the Shell Petroleum Corporation; Mr. L. P. Teas, Geologist, Humble Oil and Refining Co.; Mr. J. A. Perkins, of the Gulf Refining Co.; and Mr. W. A. Alexander, Division Superintendent, Shell Petroleum Corporation.

TABLE 1.—(Continued)

Line Number	Producing Rock						Number of Dry and/ or Near-dry Holes to End of 1936	Deepest Zone Tested to End of 1936	
	Name	Age ^f	Character ^g	Porosity ^h	Net Thickness, Average in Feet	Structure ⁱ		Name	Depth of Hole, Feet
32	"Fleming"	Mio	S	Por	31	DS	10	Discorbis	9,545
33	Discorbis, Heterostegina, Marginulina	Mio	S	Por	90	D	10	Vicksburg	10,005
34	Upper Marine Mio	Mio	S	Por	15	DS	15	MioU	6,472
35	Heterostegina, Marginulina	Mio	S	Por	50	D	51	Marginulina	10,750
36	Upper Marine Mio	Mio	S	Por	28	DS	12	MioU	6,923
37	Marginulina	Mio	S	Por	15	D	14	Marginulina	9,246
38	Miocene	Mio	S	Por	45	D	0	Miocene	10,932 Dr
39	Marginulina	Mio	S	Por	35	D	6	Vicksburg	9,000
40	Cockfield	Eoc	S	Por	10	D	0	Cook Mountain	6,838
41	Shoal River	Mio	S	Por	25	D	4	Miocene	8,739
42	Upper Marine Mio	Mio	S	Por	20	D	2	Miocene	9,602
43	Upper Marine Mio	Mio	S	Por	15	DS	12	Miocene	5,651
44	Miocene	Mio	S	Por	10	D	1	Miocene	7,210
45	Miocene	Mio	S	Por	20	D	1	Heterostegina	9,501
46	Heterostegina	Mio	S	Por	20	D	2	Frio	8,404
							1,367		

TABLE 2.—*Summary of Drilling Operations in South Louisiana*

		Location			Total Depth, Ft.
Parish, Field		Sec.	Twp.	Rge.	
		Survey	Lat.	Long.	
1	Ascension, Darrow.....	30	10 S.	2 E.	5838
2	Acadia, Bayou Mallet.....	51	7 S.	1 E.	7208
3	Calcasieu, Gillis.....	11	9 S.	8 W.	5267
4	Terrebonne, Caillou Island.....	19	23 S.	20 E.	6862
5	St. Mary, Jeanerette.....	40	13 S.	9 E.	6665
6	Plaquemines, Garden Island.....	37	23 S.	33 E.	4635
7	Lafourche, Lseville.....	27	21 S.	22 E.	5058
8	Acadia, Bayou Mallet.....	14	7 S.	1 E.	6400
9	Acadia, Jennings.....	42	9 S.	2 W.	6380
10	Iberia, New Iberia.....	71	12 S.	7 E.	6737
11	Plaquemines, Lake Hermitage.....	11	18 S.	25 E.	4646
12	Arcadia, Jennings.....	40	9 S.	2 W.	7545
13	St. Mary, Jeanerette.....	38	13 S.	9 E.	7055
14	St. Martin, St. Martinville.....	18	11 S.	6 E.	7353
15	Acadia, Jennings.....	42	9 S.	2 W.	6448
16	Iberia, New Iberia.....	54	12 S.	7 E.	4742
17	St. Landry, Port Barrie.....	4	6 S.	5 E.	3604
18	Calcasieu, Gillis.....	13	9 S.	8 W.	7377
19	Jefferson, Lafitte.....	29	17 S.	24 E.	9455
20	Jefferson, Lafitte.....	20	17 S.	24 E.	9974

Important Wildcats Drilled in 1936

	Surface Formation	Deepest Horizon Tested	Drilled by	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
				Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
1	Recent	Miocene	Humble O. & R. Co.	394		$\frac{1}{4}$	1175	625	N.S. 5822-5836
2	Recent	Marginulina	Superior-Woodley	120		$\frac{5}{16}$	650	350	N.S. 6995-7005
3	Recent	Marginulina	Fohs Oil Co.	150	7.5	$\frac{3}{8}$	600	460	N.S. 5258-5272
4	Recent	Miocene	The Texas Co.	1450		$\frac{3}{8}$		1120	N.S. 6829-6842
5	Recent	Miocene	Herton Oil Co.	1098		$\frac{5}{16}$	1000	1000	N.S. 6640-6660
6	Recent	Miocene	The Texas Co.	1067		$\frac{3}{8}$		570	N.S. 4601-4616
7	Recent	Miocene	The Texas Co.	1030		$\frac{1}{2}$		590	N.S. 4980-5047
8	Recent	Heterostegina	Superior-Woodley	325		$\frac{1}{2}$	525	500	N.S. 6385-6390
9	Recent	Marginulina	Superior	556		$\frac{1}{2}$	1360	125	N.S. 6362-6377
10	Recent	Miocene	The Texas Co.	530		$\frac{1}{4}$		600	N.S. 6687-6737
11	Recent	Miocene	Gulf Ref. Co.	150		$\frac{1}{4}$		400	N.S. 4640-4646
12	Recent	Marginulina	Shell Pet. Corp.	226		$\frac{1}{4}$	2925	2650	N.S. 7524-7545
13	Recent	Miocene	Herton Oil Co.	770		$\frac{1}{4}$		1100	N.S. 7010-7055
14	Recent	Miocene	Continental	256		$\frac{1}{4}$	2050	675	N.S. 5480-5490
15	Recent	Frio	Superior	460		$\frac{1}{2}$	850	1050	N.S. 5510-5530
16	Recent	Miocene	The Texas Co.	640		$\frac{1}{4}$		700	N.S. 4706-4740
17	Recent	Miocene	Pan-American		1½	$\frac{5}{16}$	250	350	N.S. 3542-3568
18	Recent	Lower Miocene	Union Sulphur Co.	700		$\frac{1}{4}$		1120	N.S. 7368-7377
19	Recent	Miocene	The Texas Co.	1800		$\frac{3}{8}$		1480	N.S. 9396-9439
20	Recent	Miocene	The Texas Co.	460		$\frac{1}{4}$		3160	N.S. 9912-9968

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1936.....	69	29
Number of oil wells completed during 1936.....	251	4
Number of gas wells completed during 1936.....	6	1
Number of dry holes completed during 1936.....	90	45

Oil and Gas in Michigan during 1936

BY THERON WASSON,* MEMBER A.I.M.E.

DURING 1936 the state of Michigan produced 11,868,573 bbl. This is approximately 4,000,000 bbl. less than produced in 1935. The principle reason for the decrease in production over the previous year was the rapid decline of the Crystal field, which reached its peak in October 1935. The old producing area—Mt. Pleasant, Porter, Yost-Clark—accounted for over 7,000,000 bbl. during 1936. Crystal produced a total of 2,400,000. Outstanding among the old fields were Vernon and

TABLE 1.—Oil and Gas Production in Michigan in 1936

Line Number	Field, County	Age, Years to End of 1936	Area Proved, Acres				Total Oil Production, Bbl.			
			Oil	Oil and Gas ^a	Gas	Total	To End of 1936	During 1935	During 1936	Daily Average during Nov. 1936
1	Saginaw, Saginaw.....	12	1,800	0	0	1,800	1,245,317	27,198	23,940	50
2	Gratiot, Gratiot.....	10	0	0	400	400	0	0	0	0
3	Muskegon, Muskegon.....	9	0	2,700	0	2,700	6,429,945	101,988	91,324	220
4	Mt. Pleasant, Midland, Isabella.....	9	0	8,800	0	8,800	19,115,075	1,219,064	1,006,746	2,700
5	Leaton, Isabella.....	7	1,800	0	160	1,960	1,703,990	285,153	233,114	560
6	Vernon, Isabella.....	7	1,100	0	880	1,980	3,131,488	633,361	463,044	1,340
7	Clare, Clare.....	7	0	0	300	300	0	0	0	0
8	Broomfield, Isabella.....	7	0	0	4,100	4,100	0	0	0	0
9	Porter-Yost, Midland.....	5	0	8,100	0	8,100	26,462,732	9,191,860	6,225,557	14,600
10	Hart ¹ , Oceana.....	4	1	0	0	0	116,275	11,279	0	0
11	West Branch, Ogemaw.....	3	4,800	0	0	4,800	1,432,455	523,969	764,580	2,420
12	Edmore, Montcalm.....	3	0	160	0	160	292,524	107,447	80,816	185
13	Big Rapids, Mecosta.....	3	0	0	2,200	2,200	0	0	0	0
14	Birch Run, Saginaw.....	2	260	0	0	260	99,747	35,588	63,608	145
15	Beaverton, Gladwin.....	2	480	0	0	480	307,228	23,487	283,741	850
16	Crystal, Montcalm.....	1,900	200	200	2,300	6,031,509	3,605,264	2,426,245	2,800	0
17	Six Lakes, Mecosta, Montcalm.....	2	0	0	10,000	10,000	0	0	0	0
18	New Haven, Gratiot.....	1	0	0	2,400	2,400	0	0	0	0
19	Bukeye, Gladwin.....	1/2	1,000z	0	0	1,000z	9,756	0	9,756	70
20	Ravenna, Muskegon.....	1/2	0	0	2,200	2,200	0	0	0	0
21	Sherman, Isabella.....	1/4	1,000z	0	0	1,000z	22,454	175	21,913	310
22	Clayton, Arenac.....	1/4	400	800	0	1,200	58,759	0	58,759	525
23	Miscellaneous.....						127,772	19,097	105,430	
24	Total.....		14,540	20,760	22,840	58,140	66,587,026	15,784,930	11,858,573	

* Footnotes to column heads and explanation of symbols are given on page 291.

¹Hart field discovery July 1932; abandoned in 1935.

Manuscript[†] received at the office of the Institute March 20, 1937.

* Chief Geologist, The Pure Oil Co., Chicago, Ill.

Leaton¹. The total production for all fields to the end of 1936 was 66,587,000 bbl. Most of this production has come from thin pay zones in porous limestone and dolomite of Devonian age.

During the year 820 new tests were drilled, of which 340 were oil wells, 209 gas wells and 271 dry holes. The total of 820 should be compared with 624 drilled in 1935 and 493 completed in 1934. While oil production for the first time showed a decline, gas production increased enormously because of development in the Six Lakes area of Mecosta and Montcalm Counties. On Jan. 1, 1936, Michigan had 209 producing gas wells. During the year 209 additional gas wells were completed. The combined open flow of the new wells drilled during 1936 was in excess of 4 billion cubic feet, which is approximately five times the volume of all gas wells completed in preceding years.

Tables 1 and 2 have been prepared with particular stress on the correction of areas proven in the older fields, together with production data from those areas. In addition, Table 3 has been prepared for the State of Michigan, showing total production by years by pools. Since

TABLE 1.—(Continued)

Line Number	Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells								Depth, Average in Feet		Oil Production Methods at End of 1936			
	To End of 1936	During 1935	During 1936	Maximum Daily during 1936	Completed to End of 1936	During 1936		At End of 1936						Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells		Injection into Reservoirs
						Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas ^b	Producing Gas Only	Total Producing	Flowing			Pumping		
1	0	0	0	0	282	0	11	0	65	0	0	65	1,850	1,820	0	65	62	
2	4	0	0	0	3	0	0	3	0	0	0	3	510	500	0			
3	6,395	407	263	10	411	0	15	0	85	20	25	130	2,075	2,050	0	105		
4	1,528	857	671	15	429	16	49	1	100y	175y	0	275	3,575	3,510	0	275		
5	7,737	20	57	5	80	16	6	0	61	0	4	65	G-1,245	1,240	0	61		
6	277	298	124	6	88	8	3	0	45	0	15	60	G-3,700	3,675	0	45		
7	1,019	36	241	15	7	0	0	0	0	0	7	7	G-1,405	1,395	0			
8	4,300	1,265	877	3	54	1	2	0	0	0	51	51	O-3,725	3,700	0			
9	2,718	1,575	911	37	483	96	38	0	373	48	0	421	1,420	1,415	0	421		
10	0	0	0	0	0	0	0	0	0	0	0	0	1,890	1,880	0	0		
11	0	0	0	0	194	92	18	0	169	0	2	171	1,810	1,800	0	169		
12	28	13	12	1	13	4	1	0	8	0	4	12	2,700	2,650	0	8		
13	2,222	772	1,167	57	27	11	5	0	0	0	22	22	G-1,330	1,325	0			
14	0	0	0	0	27	7	3	0	24	0	0	24	O-3,115	3,110	0			
15	0	0	0	0	45	25	7	0	22	0	0	22	1,410	1,390	0	24		
16	248	105	143	4	217	125	68	0	134	0	11	145	1,540	1,530	0	22		
17	2,373	206	2,167	19	222	162	11	0	0	0	213	213	3,885	3,870	0	22		
18	179	0	179	19	33	33	1	0	0	0	32	32	3,190	3,185	11	134		
19	0	0	0	0	3	3	0	0	3	0	0	3	1,300	1,275	0			
20	41	0	41	1	6	6	0	0	0	0	6	6	975	950	0	3		
21	0	0	0	0	3	2	1	0	2	0	0	2	3,620	3,600	0			
22	0	0	0	0	2	1	0	0	1	0	1	2	1,180	1,175	1	1		
23	0	0	0	0	19	13	3	0	16	0	0	16	2,585	2,575	1	0		
24	29,069	5,554	6,816	0	2,648	621	242	4	1,108	243	393	1,748			0	16		

¹ See map showing location of fields, *Trans. A.I.M.E.* (1936) 118, 299.

in the past it has been necessary to estimate production for the month of December, there have always been slight corrections in order to make these data agree with the totals shown by the State Geological Survey. The State Survey in some cases makes a slightly different division of area between some of the old pools. Table 3 shows as nearly as possible correct figures for every year since oil production started in Michigan and shows the consistent development that has taken place since 1925.

DISCOVERIES

The most important discovery for the year was the Buckeye field in Buckeye township, Gladwin County, where the first well was drilled in July 1936. The oil here is from the Dundee lime of Devonian age. A great deal of drilling has started as a result of this test and Buckeye will be one of the important areas in 1937, and may be expected to raise the 1937 yearly total to the 1935 level.

A large producer from the Dundee was drilled in Clayton township, Arenac County. Since its discovery two more good wells have been completed in this area, which is on the old Ogemaw-Arenac structure.

TABLE 1.—(Continued)

Line Number	Pressure, Sb. Sq. In. ^d			Character of Oil, Approx. Average during 1936					Character of Gas, Approx. Average during 1936			Producing Rock						Deepest Zone Tested to End of 1936	
	Initial	Average at End of		Maximum	Minimum	Weighted Average	Sulphur Per Cent	Base ^e	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Name	Age ^f	Character ^g	Porosity ^h	Net Thickness, Average in Feet	Structure ⁱ	Number of Dry and/ or Near-dry Holes to End of 1936	Name	Depth of Hole, Ft
		1935	1936																
1	x	x	x	y	y	43	0.7	P			Berea	MisL	S	Por	16	A	y	Sylvania	3,970
2	x	x	x	y	y	37	1.4	P	y 0		Parma	Pen	S	Por	10	MCy	y	Dundee	3,100
3	x	x	x	y	y	37	1.4	P	1,032	y	Traverse Monroe	Dev	S	Por	10	A	29	St. Peters	4,754
4	x	x	x	y	y	42	0.2	P	y 2		Dundee	Dev	L	Por	15	A	28	Sylvania	4,821
5	550	x	395	y	y	43	0.4	P	y y		Gas-Stray Oil-Dundee	Mis Dev	S L	Por S	3 5	A	25	Monroe	4,390
6	575	395	310	y	y	44	0.5	P	1,046	y	Gas-Stray Oil-Monroe	Mis Dev	S L	Por S	Af 5	33	Monroe	3,700	
7	605	556	400						1,042	y	Stray	Mis	S	Por	5	A	1	Monroe	4,055
8	550	365	y						1,060	y	Stray-Marshall	Mis	S	Por	5	A	19	Monroe	3,787
9	x	x	x	y	y	42	0.3	P	y 2		Dundee	Dev	L	Por	15	A	32	Monroe	3,677
10	x	x	x	y	y	34	y	P			Traverse	Dev	L	Por	4	A	12	Dundee	2,407
11	x	x	x	y	y	36	0.3	P			Traverse Dundee	Dev Dev	L L	Por S	A 15	A	16	Sylvania	5,404
12	900	x	x	y	y	42	y	P	y y		Stray-Marshall Traverse	Mis Dev	S L	Por S	5 5		6	Monroe	3,700
13	502	483	y						1,051	0.25	Stray-Marshall	Mis	S	Por	10	A	9	Monroe	3,798
14	x	x	x	y	y	43	0.3	P			Berea	Mis	S	Por	6	A	3	Dundee	2,733
15	x	x	x	y	y	42	y	P			Dundee	Dev	L	Por	15	A	7	Dundee	3,885
16	x	x	x	y	y	42.4	0.52	P	1,044	y	Monroe	Dev	D	Por	5	A	58	Monroe	3,496
17	515	515	475	y	y	42.4	0.52	P	1,040	y	Stray-Marshall	Mis	S	Por	25	A	16	Monroe	3,529
18	448	x	425	y	y	42.4	0.52	P	1,000	y	Stray-Marshall Dundee	Mis Dev	S L	Por Por	5 12	A A	3 2	Dundee	3,536
19	x	x	x	y	y	36	y	P			Dundee	Dev	L	Por	10	A	0	Dundee	3,663
20	720		y						885	y	Berea?	Mis	S	Por	12	y	0	Dundee	2,306
21				y	y	47.8	0.39	P			Monroe	Dev	D	Por	6	A	0	Monroe	3,763
22	x	x	x	y	y	34	0.69	P	861	y	Dundee	Dev	L	Por	20	A	0	Dundee	2,707
23	x	x	x	y	y	y	y	P	y y	y		y	y	y	y	y	y	y	y
24																			y

Big production in this area is due to the discovery of unusually well developed porosity in the Dundee limestone.

Sherman township, Isabella County, developed new production from the upper Monroe. Four new producing wells have been drilled here to the end of the year. This oil development is a northern extension from the Broomfield gas area.

Northwest of Vernon in Vernon township, Isabella County, a large producer was developed in the Monroe after treating with acid. Offset wells, however, did not prove as productive and illustrate the erratic conditions sometimes found with this type of dolomitic reservoir.

An unimportant discovery was made in Winfield township, Montcalm County, early in December. The initial production was 25 bbl. and although the well is still averaging 30 bbl. a day no further development has taken place.

DEEP TESTS

During 1936 wildcat operations were carried on in 45 counties of the Lower Peninsula and in one county of the upper Peninsula. The deepest test drilled during the year was in sec. 18, T. 32 N., R. 6 E., Alpena County. It reached a total depth of 5665 ft. and was finished as a dry hole in the St. Peter sand of Ordovician age. This test indicates the tendency to explore further north in the southern Peninsula. Another test in sec. 35, 7 N., 9 W., Kent County, reached a depth of 5575 ft., where it was abandoned as a dry hole in the Trenton limestone. An interesting test and deep stratigraphically was drilled in sec. 17, 44 N.,

TABLE 2.—*Summary of Drilling Operations in Michigan*

Important Wildcats Drilled in 1936							
	County	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested
		Sec.	Twp.	Rge.			
		Survey	Lat.	Long.			
1	Alpena.....	18	32 N.	6 E.	5665	Pleistocene	St. Peters
2	Arenac.....	10	20 N.	4 E.	1148	Pleistocene	Berea
3	Arenac.....	17	19 N.	4 E.	2972	Pleistocene	Dundee
4	Arenac.....	3	20 N.	4 E.	2506	Pleistocene	Dundee
5	Montcalm.....	20	12 N.	9 W.	3321	Pleistocene	Monroe
6	Gladwin.....	25	18 N.	1 W.	3670	Pleistocene	Dundee
7	Gladwin.....	36	17 N.	2 W.	3889	Pleistocene	Dundee
8	Gladwin.....	11	18 N.	1 W.	3616	Pleistocene	Dundee
9	Isabella.....	8	16 N.	4 W.	3937½	Pleistocene	Dundee
10	Isabella.....	34	15 N.	6 W.	3619	Pleistocene	Upper Monroe
11	Kent.....	35	7 N.	9 W.	5575	Pleistocene	Trenton
12	Lenawee.....	26	6 S.	3 E.	1290	Pleistocene	Sylvania
13	Mackinac.....	17	44 N.	9 W.	1501	Pleistocene	St. Peters
14	Muskegon.....	8	9 N.	14 W.	1212	Pleistocene	Berea
15	Tuscola.....	24	14 N.	7 E.	2832	Pleistocene	Dundee

9 W., Mackinac County, in the northern Peninsula. It was dry in the St. Peter at 1501 feet.

RECOVERY PER ACRE

While recovery per acre, as indicated by the tables attached, is relatively low for the fields of Michigan some recent production statistics show how certain leases in these fields vary from the average. The Crystal field with 2100 proven acres will have an ultimate of about 3500 bbl. per acre average for the field. One 40-acre lease in the Crystal field with four wells has produced 587,000 bbl., or 14,700 bbl. per acre. Another 36-acre lease with four wells has produced 617,000 bbl., or 17,100 bbl. per acre. A number of leases in the Porter field that are still producing have already produced over 13,000 bbl. per acre. These figures illustrate the spotted conditions found in the fields of Michigan where production is from limestone and dolomite.

PRICE OF OIL

On Jan. 1, 1936, the price paid for Michigan crude was \$1.22 per barrel. This was raised to \$1.32 on Jan. 15, where it remained until June 15, when it was raised to \$1.42. On Sept. 16 it was reduced to \$1.32 and remained at that price to the end of the year. There was no ration in Michigan during 1936.

TABLE 2.—(Continued)

Important Wildcats Drilled in 1936							
	Drilled by	Initial Production per Day		Choke, Fractions of an In.	Pressure, Lb. per Sq. In.		Remarks
		Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
1	C. W. Teater	0	0				Dry hole.
2	McClanahan	0	6		y	y	Gas from Berea.
3	T. F. Caldwell	0	1/10		y	y	Gas from Berea.
4	McClanahan	1150	0		y	y	Discovery well—Arenac
5	Daily Crude Oil Co.	21	1/2		y	y	Small oil well in Monroe.
6	Goll, Graves & Mechling	25	0		x	x	Discovery well, Buckeye.
7	Goll, Graves & Mechling	40	0		y	y	Discovery well, Crigano.
8	Wicklung Dev. Co.	1292	0		y	y	North Ext. to Buckeye.
9	Chartiers Oil Co.	?	0	3/16	x	x	Extension to Vernon field.
10	The Pure Oil Co.	672	0	x	480	x	Discovery well, Sherman.
11	Jas. E. Flanigan	0	0	x	x	x	Deep dry hole.
12	Mott & Denman	0	1/2	x	x	x	Gas from Sylvania.
13	Chas. Van Keuren	0	0	x	x	x	Test on Upper Peninsula.
14	Muskegon Dev. Co.	0	3/8	x	x	x	Discovery well, Ravenna gas field.
15	Smith Petrol. Co.	8	0	x	x	x	Small oil well.

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1936.....	51	68
Number of oil wells completed during 1936.....	329	11
Number of gas wells completed during 1936.....	204	5
Number of dry holes completed during 1936.....	90	181

TABLE 3.—*Total Production of Oil, State of Michigan*

Year	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936	Total
Pool													
Saginaw.....	4,000	94,000	434,000	231,000	113,559	89,387	61,876	63,616	55,066	48,226	27,198	23,940	1,245,868
Muskegon.....			1,928	334,601	3,157,668	1,297,962	531,147	478,728	276,174	158,425	101,988	91,324	6,429,945
Mt. Pleasant.....				27,019	1,367,836	2,378,775	2,647,879	5,795,860	3,128,804	1,512,933	1,130,326	884,153	18,873,585
Leaton.....					1,948	138,470	299,621	237,870	303,023	244,950	363,891	355,707	1,945,480
Vernon.....						22,616	244,166	322,354	538,708	907,239	633,361	463,044	3,131,488
Porter.....							944	7,381	3,354,175	7,168,161	8,317,098	4,601,728	23,449,487
Hart.....								329	45,853	58,814	11,279		116,275
Yost-Jasper.....								19,362	219,485	275,807	874,762	1,623,829	3,013,245
West Branch.....									18,974	124,922	523,969	764,580	1,432,445
Edmore.....									1,661	102,600	107,477	80,816	292,524
Birch Run.....											35,588	63,608	99,196
Beaverton.....											23,487	283,741	307,228
Crystal.....											3,605,264	2,426,245	6,031,509
Buckeye.....											9,756	9,756	9,756
Sherman.....											21,913	58,759	58,759
Clayton.....												105,430	128,314
Miscellaneous.....											20,579		
Total.....	4,000	94,000	435,928	592,620	4,641,239	3,928,229	3,785,772	6,925,665	7,941,995	10,602,759	15,776,237	11,855,573	66,587,017

MISCELLANEOUS

The handling of salt water from fields of Michigan is a difficult problem. This is particularly true of pools like Crystal, where large amounts of salt water are handled. The State Geological Survey and the State Board of Conservation have helped operators in planning for salt-water disposal.

The use of acid is standard practice in dolomite and lime wells and generally increases the initial production.

A number of extensions have been made to the oil and gas pipe-line systems operating in the state. New gas lines have been constructed from the fields to the cities of Grand Rapids and Lansing.

A very small amount of geophysical work has been done during the year and this was principally confined to electrical explorations. The deep glacial drift is the main hazard in geophysical investigations.

One of the important publications of the year bearing on the gas fields of Michigan was "Extent and Availability of Natural Gas Reserves in Michigan Stray Sandstone Horizon of Central Michigan," by E. L. Rawlins and M. A. Schellhardt. The geological map in that report was prepared by Miss Helen Martin for the State Geological Survey.

ACKNOWLEDGMENTS

Mr. Lynn K. Lee, Division Geologist, The Pure Oil Co., at Saginaw, Mich., and Mr. George H. Bell, Chief Scout of the same company, assisted in the preparation of this report. The State Geological Survey of Michigan furnished production data on oil and gas, and other information.

Oil and Gas Development in Mississippi during 1936

BY HENRY N. TOLER*

(New York Meeting, February, 1937)

OIL and gas development in Mississippi during 1936 was about the same as during the past three or four years, with less drilling activity in the proven fields; although at the end of the year there was a decided increase in interest and activity.

JACKSON GAS FIELD

Six wells were drilled in the Jackson gas field, three of which were producers and three dry holes. The gas production for 1936 was 12,968,000,000 cu. ft., which is 2,500,000,000 cu. ft. more than for any previous year. The total gas production from the field to the end of 1936 has been 58,092,000,000 cubic feet.

Thirteen producing gas wells were abandoned during the year because of encroachment of salt water. At present there are 99 producing gas wells in the field. The three oil wells on the edge of the field, which had been producing, were not produced during 1936, although they are still capable of making some oil with much salt water. The rock pressure at the end of the year was 930 lb., which is a decline of 80 lb. since the discovery of the field.

In March of 1936, the State Legislature appropriated \$115,000 to be used by the State Mineral Lease Commission in drilling some gas wells

TABLE 1.—*Oil and Gas Production in Mississippi*

Line Number	Field, County	Age, Years to End of 1936	Area Proved, Acres				Total Oil Production, Bbl.			
			Oil	Oil and Gas ^a	Gas	Total	To End of 1936	During 1935	During 1936	Daily Average Nov. 1936
1	Armory, Monroe.....	11	0	0	640	640	0	0	0	0
2	Jackson, Hinds and Rankin...	7	100 ±	0	7,500	7,600	13,444	2,240	0	0

^a Footnotes to column heads and explanation of symbols are on page 291.

Manuscript received at the office of the Institute Feb. 17, 1937.

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and a deep test well on 1300 acres of land owned by the State in the Jackson gas field.

The first gas well drilled blew out and was lost at 1100 ft., making an estimated 50,000,000 cu. ft. of gas per day. The second well drilled was 500 ft. from the blowout and was completed at the 1100-ft. level, making approximately 50,000,000 cu. ft. of gas and having a rock pressure of 480 lb. This well is now connected to the pipe line and produces approximately 1,000,000 cu. ft. of gas daily. It is interesting to note that this is the first gas to be encountered in the Jackson field at this depth and that this gas well was the first to be completed at this depth, which is the top of the Wilcox formation. There have been some differences of opinion as to whether this gas occurs normally in the sand or is a stray gas that is entering the formation by leaks in casing from other wells in the vicinity. It is the opinion of the writer that this gas has migrated into the formation from other wells. In this connection, it might be noted that three wells in the field were found to be leaking and have been repaired.

The normal producing horizon, which is Selma chalk, is encountered from 2400 to 2500 ft. The State also completed two gas wells at approximately 2500 ft., from the Selma chalk, and three or four more gas wells are to be drilled on the property. The State is selling gas from these wells to the companies operating pipe lines out of the field.

The State of Mississippi Fee No. 2, in the NW. $\frac{1}{4}$ of the NW. $\frac{1}{4}$ of sec. 25 T. 6 N., R. 1 E., which is the deep test on the State property, is drilling at 3300 ft. in sand and shale after penetrating two sills of igneous rock, one from 2945 to 3007 ft. and the other from 3026 to 3205 ft. The contract depth is 5500 ft. and if this well is carried to this depth, it will be the deepest well on top of the Jackson structure and will test formations much lower stratigraphically than have been tested before in the Jackson field.

If the writer is correctly informed, Mississippi is the first state to drill its own property for oil and gas.

TABLE 1.—(Continued)

Line Number	Total Gas Production Millions Cu. Ft.				Com- pleted to End of 1936	Number of Oil and/or Gas Wells							Depth, Average in Feet	
	To End of 1936	During 1935	During 1936	Maxi- mum Daily during 1936		During 1936		At End of 1936					Bottoms of Productive Wells	To Top of Productive Zone
						Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas ^a	Producing Gas Only	Total Producing		
1	1,686	94	36	14	4	0	2	0	0	0	1	1	2,402	2,393
2	58,092	10,291	12,968	54	139	3	13	3	0	0	99	99	2,436	2,426

AMORY GAS FIELD

No wells were drilled in the Amory gas field during the year of 1936 and the production continued to decline, only 36,000,000 cu. ft. of gas being produced during this year. The total production since the discovery of the field to date has been 1,686,000,000 cu. ft. of gas. Two of the wells that were producers went dead, leaving only one producing well in the field. This small field was discovered in 1926 and was the first production in the state.

ACTIVITY OUTSIDE PROVEN FIELDS

There were 11 wildcat wells abandoned during 1936, the deepest hole drilled being 5509 ft. The two most interesting wells of this group were the Charles Green et al. Foster Creek Lumber Co. No. 1, sec. 8 T. 3 N., R. 1 E., Wilkinson County, which had a showing of oil slightly below 3800 ft. in the Cockfield formation, and the Kirby Petroleum Co. Lanehart No. 1, sec. 22 T. 1 N. R. 2 W., Wilkinson County, which had a showing of oil from 4572 to 4579 ft. in the Miocene formation. Although the shows in neither of these wells was for a commercial producer, it is significant to have showings in the same formations that produce in other states. Undoubtedly, if the proper structural conditions are found, these formations will produce in Mississippi also.

At the end of the year seven wells were being drilled in the state and locations were made and derricks up for five others. The most interesting test being drilled is the Sun Oil Co. Scanlan and Semmes No. 1, sec. 28, T. 4 N., R. 15 W., Lamar County. This well started checking very high structurally on the upper formations and at 1650 ft. encountered anhydrite, which continued to 2522 ft. where the well encountered salt, and is still drilling slightly below this depth. This is the first salt dome to be found in Mississippi and has created considerable excitement in the oil fraternity in this part of the country.

TABLE 1.—(Continued)

Line Number	Pressure, Lb. per per In. ^d			Character of Gas, Approx. Average dur- ing 1936		Producing Rock							Deepest Zone Tested to End of 1936	
	Initial	Average at End of				Name	Age ^f	Character ^e	Porosity ^a	Net Thickness, Average in Feet	Structure ⁱ	Number of Dry and/ or Near-dry Holes to End of 1936	Name	Depth of Hole, Ft.
		1935	1936											
				B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.									
1	680	100		1,000	Dry	Hartselle	Mis	S	10	S	MU	3	Forty Payne	3,045
2	1,010	943	930	945	Dry	Selma	CreU	C	30	15	D	53	Trinity	4,027

There were six geophysical parties in the state at the end of 1936, four in South Mississippi and two in Northwest Mississippi. In addition to the shooting crews already in the state, it appears that several others will be sent into South Mississippi in search for more salt domes and other structures.

Leasing activity continued about the same during 1936 as in the past few years, a number of blocks being assembled in several counties over the state. Several of the companies are adding to the leases they already hold in South Mississippi.

As a result of the Sun Oil Company's finding a salt dome in South Mississippi and of favorable indications found by other wells, Mississippi will perhaps see more exploration work in 1937 than in any previous year.

TABLE 2.—*Summary of Drilling Operations in Mississippi*

Important Wildcats Drilled in 1936									
	County	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Remarks
		Sec.	Twp.	Rge.					
		Survey	Lat.	Long.					
1	Jones.....	31	7 N.	12 W.	4080	Hattiesburg	Wilcox	Snow Black Petroleum Co.	Dry.
2	Lamar.....	3	4 N.	15 W.	4062	Hattiesburg	Wilcox	Snow Black Petroleum Co.	Dry.
3	Lafayette.....	9	10 S.	1 W.	2465	Wilcox	Pennsylvanian	W. L. Stewart et al.	Dry.
4	Perry.....	26	1 N.	9 W.	3026	Hattiesburg	Wilcox	Fred Courson et al.	Dry.
5	Smith.....	15	4 N.	2 E.	1965	Vicksburg	Wilcox	W. J. Lewis Drilling Co.	Dry.
6	Warren.....	14	14 N.	1 E.	1690	Recent	Sparta	Harry W. Elliott et al.	Dry.
7	Warren.....	14	14 N.	1 E.	3350	Recent	Wilcox	Harry W. Elliott et al.	Dry. Show of gas.
8	Washington...	1	14 N.	8 W.	3455	Recent	Cretaceous	Mid-Continent Development Co.	Dry.
9	Wilkinson.....	8	3 N.	1 E.	5033	Miocene	Claiborne	Charles Green et al.	Dry. Show of oil.
10	Wilkinson.....	22	1 N.	2 W.	5509	Miocene	Claiborne	Kirby Petroleum Co.	Dry. Show of oil.
11	Wilkinson.....	38	2 N.	3 W.	5026	Miocene	Claiborne	T. S. Stoneman	Dry.

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1936.....	1	7
Number of oil wells completed during 1936.....	0	0
Number of gas wells completed during 1936.....	3	0
Number of dry holes completed during 1936.....	3	11

Oil and Gas in Missouri in 1936

BY FRANK C. GREENE,* MEMBER A.I.M.E.

(New York Meeting, February, 1937)

DRILLING for oil and gas in Missouri continued at a slightly lower rate than has been prevailing. A summary of operations for the past few years as compiled and published by the Missouri Geological Survey and Water Resources is as follows:

TABLE 1.—*Oil and Gas Wells and Dry Holes Drilled in Missouri in 1933-34 and 1935-36^a*

County	1933-34					1935-36				
	Oil	Gas	Dry	Initial Production of Oil, Bbl.	Open Flow of Gas Wells, Cu. Ft.	Oil	Gas	Dry	Initial Production of Oil, Bbl.	Open Flow of Gas Wells, Cu. Ft.
Bates.....		1	6		431,000					
Cass.....	8	7	15	95	1,357,440	16	4	14	164	800,000
Clay.....		8	13		1,337,000					
Clinton.....		19	8		8,051,000		2	2		2,529,000
Henry.....			1							
Jackson.....	2	55	58	5	15,401,616	17	38	58	42	12,003,968
Platte.....						2	2	4	5	55,000
Totals.....	10	90	01	100	26,578,256	35	46	78	211	15,387,968

^a Missouri Geol. Survey and Water Resources, 59th Bien Rept. of State Geologist, App. VIII (1937).

Two oil pools are being developed in Cass County. Neither area has been drilled completely, and detailed descriptions will not be given at this time. In the Endicott pool in the southern part of T. 44 N., R. 33 W., oil is found in the Warrensburg sand, which is now considered to be the Big Lake sand of eastern Kansas. The top of the sand is about 125 ft. below the Hertha limestone. The best well is reported to have made 14 bbl. per day for the first four days. The oil is 30° to 32° Bé. gravity. This is the only pool in the state, aside from the older areas on the east and west edges of Lees Summit, Jackson County, that is producing oil from the Warrensburg sand. Drilling continues in the Knoche pool in the central part of T. 46 N., R. 33 W., where the oil is found in the Squirrel sand. The oil produced by both these pools is sold by truck in Kansas City.

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In Jackson County additional wells were drilled in old pools in the vicinity of Martin City, T. 47 N., R. 33 W., the Unity pool in T. 48 N., R. 32 W., and the east Lees Summit pool in T. 47 N., R. 31 W.

Oil was found in Platte County in sec. 7, T. 50 N., R. 33 W., in a producing horizon new to the state, but the development to date scarcely warrants designating the area an "oil pool," as only two wells have been completed. The oil is found in a sand below the Lexington black shale, and is believed to be a sandy phase of the Upper Fort Scott limestone, and possibly the equivalent of the "Wheeler sand" of Oklahoma. The oil is 26° Bé. gravity. When the first well was completed, it flowed naturally without being shot. When placed on the pump it is reported to have made 4½ bbl. per day for a 30-day test period.

The main gas developments were in sec. 16, T. 49 N., R. 32 W., Jackson County, where an initial daily output of 5,500,000 cu. ft. was found in the Squirrel sand, and in sec. 18, T. 55 N., R. 31 W., Clinton County, where a well obtained an initial daily output of 2,149,000 cu. ft. in the Squirrel sand.

Oil and Gas Development in Montana for 1936

BY EUGENE S. PERRY*

THE most outstanding event in oil and gas development in Montana during 1936 was the discovery of oil in the Baker-Glendive gas field, in the extreme eastern part of the state. Other notable achievements were small extensions in the Cut Bank oil field; continued favorable results of acidization in the Kevin-Sunburst oil field; and the discovery of oil and gas in commercial quantities about 20 miles southwest of Billings, on what is known as the Mosser dome. Several wildcat wells were drilled. For the coming year of 1937, it is anticipated that the main activities will be confined to drilling in or near known fields.

During 1936 Montana had seven fields producing oil, but over 95 per cent of oil production came from four fields, which in order of importance are: Cut Bank, Kevin-Sunburst, Cat Creek and Pondera. Total production for the state was 5,850,893 bbl., which is 1,251,761 bbl. more than the total for 1935. Natural gas was produced and marketed from eight fields, most important being Cut Bank, Baker-Glendive, Kevin-Sunburst and Dry Creek. These four fields accounted for over 85 per cent of total state gas production, which is slightly greater than the 1935 production of nearly 18 billion cubic feet. Increase in gas consumption is due in part to increase in smelter operation. More detailed information pertaining to the various fields is given in Table 1.

In the Baker-Glendive field a test 8186 ft. deep, 15 miles southeast of Baker, was completed by the Montana-Dakota Utilities Co. in 1936. The first gas-bearing sandstone (Judith River horizon, Upper Cretaceous) was found at a depth of 528 ft., and a second sand at 1167 ft. Sandstones of the Dakota formation, in which occurred water, were found from 3724 to 3853 ft. White sandstone correlated with the Tensleep (Minnelusa) formation of Pennsylvanian age was found from 5631 to 5751 ft. deep. The lower 1900 ft. of the well (below 6278 ft.) was essentially in limestone and dolomite, and information on correlation of formations in this mass of sediments is not available at this time. The upper portion of this part of the well contained much anhydrite. Cherty and dolomitic limestone below 7000 ft. may be equivalent to limestones of the Madison formation. The thickness of strata beneath the Dakota formation was

Manuscript received at the office of the Institute April 16, 1937.

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much greater than was anticipated. This may be due in part to a thickening of the Sundance and Spearfish formations, but in part it is due to the presence of a group of strata of upper Mississippian age (Big Snowy group of Montana) not yet observed in the Black Hills area.

A considerable amount of oil, unofficially reported to be several hundred barrels per day, was found in limestone between depths of 6500 and 6800 ft. (about 6000 ft. beneath the main gas horizon). After heavy acidization much water appeared. Good showings of oil were found in the lower part of the hole, which was also acidized. Attempts to bring in the well as a commercial producer are being made at present. This well was located on or near the high point of the Baker-Glendive anticline, a narrow fold nearly 100 miles long and with about 500 ft. closure on the critical side. Gas occurs in shallow horizons throughout its length. A second deep test, $\frac{1}{2}$ mile north of this well, found oil at 6751 ft.; and a third deep test (7264 ft.), about five miles north of Baker, found salt water in the lower horizons.

Most extensive drilling in 1936 was in the Cut Bank field, where 124 wells were sunk. Six holes were drilled and abandoned bordering the field on the south. Drilling within the field produced 100 oil wells and 9 gas wells, and 15 wells were dry or abandoned. Most of the drilling was in the south end of the field and brought about small extensions of the productive area. The most notable well of 1936, on the west edge of this field, was drilled through the productive horizons to a depth of 2978 ft., with but small amounts of oil showing. A 40-quart shot of nitroglycerin was then discharged through casing at a depth of about

TABLE 1.—*Oil and Gas Production in Montana*

Line Number	Field, County	Age, Years to End of 1936	Total Oil Production, Bbl.		
			To End 1936	During 1935	During 1936
1	Baker-Glendive, Fallon, Wibaux, Dawson.....	22	none		
2	Border or Red Coulee, Toole.....	6	606,152	1	1
3	Bowdoin-Saco, Phillips, Valley.....	20	none		
4	Bowes, Blaine.....	10	none		
5	Boxelder, Hill.....	5	none		
6	Cat Creek, Petroleum, Garfield.....	15	13,406,311	292,750	254,239
7	Cut Bank, Glacier.....	10	6,946,527	2,323,141	3,332,440
8	Devil's Basin, Musselshell.....	17	16,684	3,075	none
9	Dry Creek, Carbon.....	9	783,527	60,421	212,561
10	Elk Basin, Carbon.....	20	863,503	8,218	11,680
11	Hardin, Big Horn.....	7	none		
12	Kevin-Sunburst, Toole.....	14	31,594,328	1,425,846	1,585,909
13	Lake Basin, Stillwater.....	9	287,935	18,055	15,144
14	Pondera, Pondera, Teton.....	10	4,448,039	431,233	421,395
15	Soap Creek, Big Horn.....	16	69,613	20,344	4,210
16	Whitlash, Sweetgrass Hills, Toole, Liberty.....	12	none	14,555	13,179
17	Mosser.....	0			136
18	Bannatyne, Teton.....	10	63,097	1,494	none

2860 ft., where good showings of oil had been previously noted. This is an upper sand (Sunburst, Lower Cretaceous), not commonly productive in this field. The main productive sand (Cut Bank sand) lies at the base of the Kootenai formation 50 to 100 ft. beneath the Sunburst sand. Following the shot the well flowed as much as 2000 bbl. per day, settling to about 650 bbl. per day. Three offset wells failed to find large production. Average settled production per well per day for the Cut Bank field ranges from 35 to 40 bbl. Practically all oil is raised to the surface by pumping.

The so-called Mosser dome, southwest of Billings, is a "half-dome" lying adjacent to the Fromberg fault zone. This is a down-dropped fault block $\frac{1}{4}$ to 1 mile wide and about 25 miles long, which trends tangentially to the Pryor (Big Horn) mountain uplift on its northwestern flank. Three wells have been completed on the dome; one is reported to have yielded 15,000,000 cu. ft. of gas per day, and one to have yielded 100 bbl. of oil per day by pumping. The producing horizon is at the base of the Cloverly (Dakota) formation at a depth of about 1010 feet.

Continuation of acidization of the oil-bearing upper portion of the Madison (Mississippian) limestone in the Kevin-Sunburst and Pondera fields resulted in continued increases in oil production, not only in new wells giving only "shows" of oil, but in some abandoned wells. In all, 88 wells were acidized in these fields in 1936. Practically all were commercial after acidization. Since the beginning of acidization in

TABLE 1.—(Continued)

Line Number	Total Gas Production, Cu. Ft.		Wells Completed						
	To End of 1935	During 1935	During 1936			Total to End of 1936			
			Oil	Gas	Abandoned or Shut In	Producing		Abandoned or Shut In	Total Drilled
						Oil	Gas		
1	42,023,872,178	4,696,245,376	1	2	0	1	90	114	205
2						23	1	7	31
3	2,330,402,800	750,694,000					24	4	28
4	4,305,838,049	470,088,000					8	1	9
5	^a	^a					2	1	3
6			2			192		98	290
7	21,865,937,000	7,205,384,000	100	9	15	334	45	49	428
8									42
9	3,225,334,000	689,354,000				8	4	8	20
10									30
11	^a	64,997,000		6			26		26
12	24,597,468,440	2,527,916,600	56	2	10	1,120	161	1,043	2,324
13	44,401,000 ⁴	none				5		35	40
14						157		21	178
15						5		7	12
16	2,612,693,000	654,419,000				6	6	16	28
17			1	1		1	1		2
18									

¹ Included under Kevin-Sunburst.

² Included with Bowes.

³ No record prior to 1935.

⁴ Total production unknown, gas used for carbon-black manufacture.

Montana, over 300 wells have been treated with acid. The amount used per well ranges from 500 to 1000 gal. Production was increased from 5 to 50 bbl. per day. The use of hydrochloric acid instead of high explosives for increasing oil production in these fields is now an accepted procedure, and this treatment is reviving oil fields that were well along on their normal declines.

Oil and Gas Development in New Mexico

By E. H. WELLS,* MEMBER A.I.M.E., AND A. ANDREAS†

GREATER progress than in any previous year was accomplished by the oil industry in New Mexico in 1936. The total number of completions in the state was 631, of which 549 were oil wells, 21 were hydrocarbon gas wells, three were carbon dioxide gas wells, and 58 were dry holes.

The total oil production for the year was 26,804,446 bbl. Compared with the production for 1935 of 20,228,947 bbl., this represented a gain of 32.5 per cent. Of the total production, 25,337,382 bbl. came from Lea County. The average daily nonmarginal well allowable for that county was 115 bbl. the first of the year and 86 bbl. at the close. Production was regulated by the New Mexico Oil Conservation Commission,

TABLE 1.—*Oil and Gas Production in New Mexico*

Line Number	Field, County	Age, Years to End of 1936	Area Proved, Acres			
			Oil	Oil and Gas ^a	Gas	Total
1	Ute Dome, San Juan.....	14	0	0	640	640
2	Hogback, San Juan.....	14	160	0	0	160
3	Artesia (Getty-Jackson-Majamar), Eddy.....	13	10,660	0	2,840	13,500
4	Rattlesnake, San Juan.....	12	640	0	0	640
5	Aztec-Bloomfield, San Juan.....	12	90	0	5	95
6	Table Mesa, San Juan.....	11	100	0	0	100
7	Blanco, San Juan.....	9	0	40	0	40
8	Hospah, McKinley.....	9	50	0	0	50
9	Jal, Lea.....	9	2,560	200	560	3,320
10	Kutz Canyon, San Juan.....	9	0	0	1,200	1,200
11	Hobbs, Lea.....	8	1,520	8,240	0	9,760
12	Eunice, Lea.....	8	14,600	0	0	14,600
13	Cooper, Lea.....	7	4,000	0	0	4,000
14	Lea & Lea Ext., Lea.....	7	520	0	0	520
15	Monument, Lea.....	2	10,520	0	0	10,520
16	Red Mt., McKinley.....	1	20	0	0	20
	Total.....		45,440	8,490	5,245	59,165

^a Footnotes to column heads and explanation of symbols are given on page 291.

Manuscript received at the office of the Institute March 24, 1937.

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consisting of the Governor, the Commissioner of Public Lands and the State Geologist.

Acidizing the producing horizons before completing the wells was effectively carried on as in the past, but some of the wells that had large potentials when first brought in were not acidized. Because of the flat 40-acre unit allowable in the Lea County fields, except Hobbs and Monument, a number of operators did not attempt to complete wells in those fields with the largest possible potential.

Proration by the Oil Conservation Commission was continued in Lea County on the same basis as in the preceding year, except in the Monument field. In that field the proration plan was changed from a flat 40-acre unit allocation to an allocation based 80 per cent on acreage and 20 per cent on bottom-hole pressure. The daily allocations for the state were set by the Oil Conservation Commission. For January 1936 the allocation was 62,000 bbl. and for December it had been increased to 86,200 bbl.

During the year four new oil fields were discovered. These consisted of the Penrose and Hardy fields in the sand-belt area in Lea County near the Texas line, a field between the South Eunice and Lynn fields in Lea County, and the small Red Mountain field in McKinley County.

SOUTHEASTERN NEW MEXICO

Hobbs Field.—The Hobbs field in Lea County continued to be the largest producing field in the state, with a total production of 9,052,129

TABLE 1.—(Continued)

Line Number	Total Oil Production, Bbl.				Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells		
	To End of 1936	During 1935	During 1936	Daily Average during Nov. 1936	To End of 1936	During 1935	During 1936	Maximum Daily during 1936	Completed to End of 1936	During 1936	
										Completed	Abandoned
1	0	0	0	0	3,248	681	447.5	y	3	0	0
2	1,741,429	68,816	84,657	323	0	0	0	0	7	0	0
3	7,265,411	844,443	1,071,806	3,292	x	750	x	x	376	22	x
4	2,527,599	260,111	278,293	878	0	0	0	0	43	9	5
5	26,279	4,166	2,113	7.7	0	0	0	0	28	1	4
6	423,957	34,413	28,595	102.6	0	0	0	0	6	0	0
7	1,119	0	0	0	131	18	24	0.2	1	0	0
8	0	0	0	0	0	0	0	0	3	0	0
9	5,438,311	1,405,161	1,104,417	3,378	25,544x	12,016x	13,528	x	96	28	4
10	0	0	0	0	5,474	735	1,192	x	11	3	0
11	73,579,412	11,068,664	9,052,129	23,009	112,146x	15,439	14,516	x	258	7	2
12	13,458,049	3,314,720	8,238,660	30,029	30,055x	9,197	20,858	x	378	241	7
13	6,029,902	2,531,852	2,929,397	7,973	21,420x	6,789x	14,631	x	113	18	0
14	6,006,239	459,207	432,871	1,012	0	0	0	0	35	0	6
15	3,817,302	237,394	3,579,908	12,311	8,409x	244x	7,165	x	263	235	0
16	1,600y	0	1,600y	5	0	0	0	0	4	4	1
	121,316,609	20,228,947	26,804,446		206,427	45,869	72,361.5		1,625	568	29

bbl., although only seven wells were drilled during the year and two of these on the northwest flank of the structure were later abandoned. The total potential at the end of the year was 2,129,526 bbl. for 244 units of 40 acres each and 255 producing wells.

Eunice Field.—In the Eunice field, Lea County, the second largest producing field in the state, drilling was chiefly in the eastern and northern parts, without defining the limits of the field. The total number of completions in the Eunice field proper consisted of 197 oil wells, two gas wells, and five dry holes. There were 365 productive 40-acre units at the end of the year. In the South Eunice field four small wells were completed.

Monument Field.—The greatest drilling activity during the year was in the Monument field, Lea County, where 235 producing wells and only two dry holes were completed. These dry holes were the Gulf Burk No. 1, in sec. 28, T. 19 S., R. 37 E., which encountered sulphur water in lime at 4020 ft., and the Repollo Bolding No. 1 in sec. 10, T. 20 S., R. 37 E., which was abandoned at 4257 ft. after encountering sulphur water in lime at 4145 to 4257 ft. At the end of the year the limits of the field had not been defined on the north, west and south. Less than two miles of unproven area separated the Monument field from the Eunice field to the south, and these two fields are evidently parts of one continuous field. The total producing wells and also the 40-acre units in the Monument field numbered 263 at the close of the year.

Cooper, Mattix, Langlie and Jal Fields.—In the Cooper, Mattix and part of the Langlie fields, Lea County, there were 19 completions, 13 being

TABLE 1.—(Continued)

Line Number	Number of Oil and/or Gas Wells					Depth, Average in Feet		Oil Production Methods at End of 1936			Pressure, Lb. per Sq. In. ^d			Character of Oil, Approx. Average during 1936				
	At End of 1936					Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells			Average at End of			Gravity A.P.I. at 60° F.				
	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas ^e	Producing Gas Only	Total Producing			Flowing	Pumping	Gas-lift	Initial	1935	1936	Maximum	Minimum	Weighted Average	Sulphur, Per Cent	Base ^e
1	0	0	0	3	3	2,350	2,285	0	0	0	720	600	550					
2	0	7	0	0	7	714	705	7	0	0	y	y	y	60	60	60	0.08	P
3	z	241	y	y	241y	2,251	z	35	206	0	z	z	z	39.6	35	37.1	0.87	M
4	10	28	0	0	28	808	784	4	24	0	y	y	y	87	60	60	0.05	P
5	6	12	0	0	12	1,075	750	0	12	0	0	0	0	58	50	55	0.08	P
6	0	6	0	0	6	1,337	1,325	0	6	0	0	0	0	57	56	56.5	0.04	P
7	0	0	0	1	1	4,550	4,250	0	0	0	1,200	1,000y	950y	55	50	54	0.13	P
8	3	0	0	0	0	1,651	1,640	0	0	0				30.2	29	29.7	0.15	M
9	13	64	y	15	79	3,327	z	42	16	6	z	y	y	y	y	28.5	1.97	P
10	1	6	0	10	10	1,900	1,840	0	0	0	565	515	500	0	0	0		
11	4	46	206y	0	252	4,174.4	4,050	234	15	3	1,550	e1,302	e1,242y	35.5	35	35.3	1.47	M
12	7	365	0	0	365	3,879	z	347	15	3	z	1,332y	y	35	32	33.5	1.65	P
13	9	99	0	4	103	3,570	z	67	12	20	z	1,326y	1,300y	0	0	29	y	P
14	0	13	0	0	13	3,771	z	0	13	0	0	0	0	0	0	27	1.53	P
15	0	263	y	0	263	3,935	z	260	3	0	1,427	1,427	1,409	0	0	34	y	P
16	0	2	0	0	2	457	438	0	2	0	0	0	0	43	41	42	0.01	M
53	1,146	206y	33	1,385y				996	324	32								

oil wells, five gas wells and one a dry hole. The Cooper field continued to produce large amounts of water. Completions in the Jal field and the other part of the Langlie field consisted of 22 oil wells, six gas wells and three dry holes.

Artesia-Jackson-Maljamar Area.—In the Artesia-Jackson-Maljamar area, in Eddy and Lea Counties, developments were of moderate importance. Of the 24 completions, 19 were oil wells, three were gas wells and two were dry holes. Most of the drilling was in proven and semi-proven areas.

Penrose Area.—The first new field discovered in New Mexico during 1936 was the Penrose field in T. 22 S., R. 37 E. On Jan. 9, Penrose and Rowan completed their Cary No. 1 in sec. 22, T. 22 S., R. 37 E., at a depth of 3555 ft. The initial production was 180 bbl. and 500,000 cu. ft. gas. At the end of the year there were 16 completed oil wells and no dry holes.

Production in the Penrose and Hardy areas is obtained from the Ramsey sand, which has been tentatively correlated with the Bowers sand of the Hobbs pool where it is several hundred feet above the "White Lime," the main producing horizon. The Ramsey sand is from 150 to 400 ft. thick.

Hardy Area.—On March 18, the Barnsdall Oil Corporation completed the Hardy No. 1 in sec. 29, T. 21 S., R. 37 E. at a depth of 3800 ft. in the Ramsey sand, with an initial production of 225 bbl. daily. Nine oil wells and no dry holes were drilled in this area during the year.

TABLE 1.—(Continued)

Line Number	Character of Gas, Approx. Average during 1936		Producing Rock						Number of Dry and/ or Near-dry Holes to End of 1936	Deepest Zone Tested to End of 1936		Refer- ence to Text ¹
	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Name	Age ²	Character ³	Porosity ⁴	Net Thickness, Average in Feet	Structure ⁵		Name	Depth of Hole, Feet	
1	1,060	<i>y</i>	Dakota Ss	CreU	S		60	D	0	Dakota-CreU	2,350	A
2	0	0	Dakota Ss	CreU	S		9	D	9	McElmo-CreL	1,225	
3	<i>y</i>	<i>y</i>	Upper San Andreas	Per	D	<i>y</i>	<i>z</i>	AM	108	Pennsylvanian?	6,683	
4	0	0	Dakota Ss	CreU	S		24	AF	17	PenU	7,370	(P.B. to 6771)
5	1,153	<i>y</i>	Farmington Ss	CreU	S		<i>z</i>	S	38	Lewis Sh CreU	2,665	A
6	0	0	Dakota Ss	CreU	S		7	A	7	Chinlee-TriasU	3,010	A
7	1,050	<i>y</i>	Pictured Cliffs	CreU	S		<i>z</i>	H	18	Mesa Verde-CreU	4,550	A
8			Mesa Verde	CreU	S		11	DF	12	Mancos-CreU	3,282	A
9	<i>y</i>	<i>y</i>	White Lime	Per	D	Cav		A	11	San Andreas-Per	4,125	A
10	1,050	<i>y</i>	Pictured Cliffs	CreU	S		60	H	12	Mesa Verde CreU	4,400	A
11	1,150	1.98	White Lime	Per	D	Cav	123	A	11	San Andreas Per	4,500	A
12	<i>y</i>	<i>y</i>	White Lime	Per	D	Cav		A	10	San Andreas Per	4,310	
13	<i>y</i>	<i>y</i>	White Lime	Per	D	Cav		A	4	L. San Andreas Per	5,095	A
14	0	0	White Lime	Per	D	Cav		AM	16	San Andreas Per	4,046	
15	<i>y</i>	<i>y</i>	White Lime	Per	D	Cav		A	2	San Andreas Per	4,506	
16	0	0	Mesa Verde	CreU	S		13	AF	7	Mesa Verde CreU	665	
									282			

Lynn Extension.—The third field to be opened in Lea County during 1936 was a field between the South Eunice and Lynn fields. During the latter part of December the Continental Oil Co. completed the Farney No. 1 in sec. 5, T. 23 S., R. 36 E. at a depth of 3769 ft. The initial production was 912 bbl. and 600,000 cu. ft. gas through a $\frac{3}{4}$ -in. choke. This well may be an extension of the Lynn field. It is over 2 miles north of the producing wells in the Lynn field and 2 miles south of the Texas Dean No. 1, a dry hole drilled in sec. 28, T. 22 S., R. 36 E.

NORTHWESTERN AREA

San Juan County.—In San Juan County, in the northwestern part of the state, drilling was confined chiefly to the Rattlesnake oil field and the Kutz Canyon gas field. There were 15 completions in the county, consisting of 10 oil wells, three gas wells, and two dry holes.

McKinley County.—The Red Mountain field in McKinley County was discovered in March, 1936. The surface rocks and producing horizon are the Mesa Verde formation of Cretaceous age. Production is found at a depth of approximately 440 ft. The structure is a faulted anticline, and the productive area appears to be very small. The oil has a gravity of 42° A.P.I. The largest producer pumped 25 bbl. daily. By the end of the year 11 wells had been drilled, of which only four were oil wells. Production for the year was approximately 1600 barrels.

NORTHEASTERN AREA

Torrance County.—No commercial oil wells were drilled in the northeastern part of the state, and the chief developments were in connection

TABLE 2.—*Summary of Drilling Operations in New Mexico*

Important Wildcats Drilled in 1936				
	County or Local Division	Location		
		Sec.	Twp.	Rge.
		Survey	Lat.	Long.
1	Lea.....	29	21 S.	37 E.
2	Lea.....	18	21 S.	33 E.
3	Lea.....	5	23 S.	36 E.
4	Lea.....	27	23 S.	35 E.
5	Lea.....	14	20 S.	37 E.
6	Lea.....	13	25 S.	37 E.
7	Lea.....	24	18 S.	38 E.
8	Lea.....	35	22 S.	37 E.
9	Lea.....	29	16 S.	35 E.
10	Lea.....	33	18 S.	37 E.
11	Lea.....	13	16 S.	36 E.
12	Lea.....	22	22 S.	37 E.
13	Lea.....	17	21 S.	32 E.
14	Lea.....	14	11 S.	32 E.
15	Chaves.....	15	11 S.	26 E.
16	McKinley.....	29	20 N.	9 W.
17	Torrance.....	17	9 N.	8 E.
18	Union.....	2	22 N.	34 E.

with carbon dioxide gas. At the Wilcox dome, in Torrance County, two commercial carbon dioxide wells were completed, making a total of five commercial wells. Gas from the wells was piped to the plant of the Witt Gas & Ice Co. and made into "dry ice." The capacity of the plant is 30 tons per day, but it did not operate at full capacity.

Harding County.—The second commercial carbon dioxide field discovered in New Mexico is the Bueyeros field in Harding County. One commercial carbon dioxide gas well was completed, this being the second commercial well in the area. At the end of the year four other wells were drilling. Two "dry-ice" plants were under construction in the field at the end of the year.

ACKNOWLEDGMENTS

The writers are especially indebted in the preparation of this New Mexico summary to Mr. C. G. Staley, Proration Umpire for Lea and Eddy Counties, New Mexico; to his assistant, Mr. C. P. Miller; and to Mr. J. A. Frost, District Engineer, United States Geological Survey, Farmington, New Mexico.

TABLE 2.—(Continued)

Important Wildcats Drilled in 1936

	Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Initial Production per Day		Choke or Bean, Fractions of an Inch	Remarks
					Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		
1	3800	Tertiary	Permian	Barnsdall	225			
2	3813	Quaternary	Permian	Culberson & Irwin				Abandoned
3	3760	Tertiary	Permian	Continental	912	0.6	3/4	
4	4130	Tertiary	Permian	Gulf				Abandoned
5	P.B. 4064	Tertiary	Permian	C. & G.	62			
	4075							
6	3903	Tertiary	Permian	Gulf		7.5		
7	P.B. 4587	Tertiary	Permian	Gulf				Abandoned
	4883							
8	3706	Tertiary	Permian	Humble				Abandoned
9	5300	Tertiary	Permian	Magnolia				Abandoned
10	4506	Tertiary	Permian	National Securities				Abandoned
11	5065	Tertiary	Permian	Oil Well Drilling				Abandoned
12	3555	Tertiary	Permian	Penrose & Rowan	180			
13	3752	Quaternary	Permian	Todd				Abandoned
14	5026	Tertiary	Permian	Vierson-Brown				Abandoned
15	1283	Permian	Permian	Commanche Drig. Co.	7			
16	460	Cretaceous	Cretaceous	Forth, Wm.	20			
17	2100	Permian	Pennsylvanian	The 48 Pet. Co.				Abandoned in granite
18	2925	Tertiary	Permian	Olson Drig. Co.				Abandoned in granite

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1936.....	79	20
Number of oil wells completed during 1936.....	543	6
Number of gas wells completed during 1936.....	23	1
Number of dry holes completed during 1936.....	27	31

Petroleum and Natural Gas in New York in 1936

By D. H. NEWLAND,* MEMBER A.I.M.E., AND C. A. HARTNAGEL†

DETAILED production statistics listing the operations according to producing sands, districts, etc., are not available for New York State and are scarcely obtainable without extraordinary effort and expense, hardly warranted by the current rate of developments. The oil industry is practically stabilized, so far as exploration for new sources of supply are concerned; no new pools have been tapped in the last 25 or 30 years. There is little prospect of extending the boundary of the oil fields beyond their present limits, though possibly some additional reserves may be found below the present productive sands. Natural gas, on the other hand, is not restricted to such confined areas. Drilling for gas has been fairly active, under the stimulation of some important finds in formations that previously were overlooked. The year's field operations will be covered somewhat fully.

Oil production, which has been steadily advancing for a number of years, showed a further moderate gain in 1936. The output for 11 months (figures for December are not yet available) was 4,217,000 bbl., indicating a total for the year of around 4,600,000 bbl. The increase was about 10 per cent, a rate maintained for some time. Prices were more satisfactory than in the preceding five years, with an advance to \$2.57 a barrel before the year's close. New York State yield is all paraffin-base, in the same class with high-grade Pennsylvania oil. Most of the output is now obtained by the water drive, which has given a new lease of life to the fields and promises to bring the total to about 200,000,000 bbl. before the known acreage has been exhausted by this method. Before its introduction the annual production was under 1,000,000 bbl. a year. The fields cover an aggregate area of 55,000 acres, with some 17,000 wells in operation.

DEVELOPMENT

Exploring for natural gas in New York in 1936 outside of the old established pools continued actively, as in the previous year. There was an increase in total initial production. Operations were conducted in nine counties of the central and western parts of the state, and 43 wells

Manuscript received at the office of the Institute Feb. 17, 1937.

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were completed, of which 23 were producers. The combined initial open-flow capacity of the 23 producers was 293,000 M. cu. ft. per day. At the end of the year 10 wells were drilling.

The greatest development took place in the new State Line pool of Allegany County, in the towns of Alma and Willing, both bordering on the State of Pennsylvania. In Alma eight wells, all productive, were drilled and in Willing six wells, four of which were producers. The production from the 12 wells accounted for about 97 per cent of the total new supplies of natural gas. Initial production of the wells ranged from 7500 to 34,000 M. cu. ft. daily, or an average flow per well of 24,000 M. cu. ft. The productive formation is the Oriskany sandstone, reached at depths of from about 4600 to 4900 ft. Other tests to the Oriskany sandstone in Allegany County included three in the town of Amity and one each in the towns of Allen, West Almond and Angelica. In depth these wells ranged from 3200 to 4200 ft. One well reported a small production of 6000 cu. ft.; the rest were dry.

In Steuben County four wells were completed as Oriskany tests; in Dansville, Howard, Avoca and Hornellsville townships, respectively. The Howard well had a reported flow of 30,000 cu. ft.; the others were dry. One well, in the town of Greenwood, Steuben County, completed late in 1935 with an initial flow of over 16 M. cu. ft., went to salt water before it had been connected to the pipe line.

Four wells were drilled to the white Medina sandstone in the town of Leon, Cattaraugus County. All found gas with initial flows of 3200, 2500, 900 and 50 M. cu. ft. In depth the wells averaged about 3600 ft. The horizon of the Oriskany sandstone was drilled through in these wells but no sand was present.

In Chautauqua County a test to the Medina sandstone in the town of Charlotte reached a depth of 4030 ft. without finding paying gas. A well 2120 ft. deep in the town of Hanover found a gas flow in the Medina of 14 M. cu. ft. In the town of Portland an attempt to drill a deep well was abandoned after failure to land the 10-in. drive pipe, which had reached a depth of 436 ft. in glacial drift. In the Arkwright field, developed some years ago, the most noteworthy feature of the year was the bringing in of a well with a flow of 1250 M. cubic feet.

A few miles east of the Wayne-Dundee field three wells were drilled in the town of Hector, Schuyler County. The Oriskany sand was found in only one of these wells and all were dry. An effort to extend the limits of the Pavilion field was made by the drilling of a well in the town of York, Livingston County. The well was drilled to a depth of 1420 ft. but was dry in the Medina.

One Medina sandstone test in Aurelius township, Cayuga County, was drilled to a depth of 1850 ft. and had a reported flow of 30,000 cu. ft. One well was drilled in the town of Brookfield, Madison County. The

Medina here lies at a depth of about 1900 ft. The Oriskany is also present. Only small flows of gas were found at several horizons in the well.

In Oneida County six wells to the Trenton limestone were drilled, of which two were producers. One of the wells in the town of Rome reported a flow of gas of 200 M. cu. ft. at 737 ft. in the Trenton limestone. The other producer in the town of Camden was drilled to a depth of 1365 ft. and had a flow of 350 M. cu. ft. During the year a franchise was granted to the Camden Natural Gas Co. for supplying the village of Camden with gas from wells drilled in that vicinity during the past three years. Delivery of the gas has already started.

PIPE LINES

Additional facilities for marketing natural gas in New York State have been provided by the extension of existing pipe lines or the building of new ones. Through the extension of the pipe lines of the Columbia Gas & Electric Corporation, natural gas is now delivered as far south as Rockland County, only 15 to 20 miles above New York City.

A new 14-in. pipe line is under construction by the Cabot Gas Corporation from the Pennsylvania fields to the city of Rochester. The pipe line is 92 miles long and the gas will be used mainly by the Eastman Kodak Co., which has a three-year contract to take a maximum of 5,500,000 M. cu. ft. of gas annually. The pipe line will also supply communities along its line and will sell gas to the Pavilion Gas Co. for redistribution to communities near Rochester.

Another pipe line completed during the year was that of the Penn-York Gas Corporation (Cities Service Co.). This pipe line originates in Potter County, Pennsylvania, enters New York State near Wellsville, Allegany County, and extends as a 10-in. line 63 miles long to near Arcade, Wyoming County. At this point the line branches. One 8-in. line extends 43 miles westerly to Sheridan, Chautauqua County. The other, also an 8-in. line, extends 31 miles northerly to a place near East Lancaster, Erie County.

Oil and Gas Development in Ohio for 1936

BY J. E. SCHAEFER*

(New York Meeting, February, 1937)

A SUMMARY of oil and gas development in Ohio for 1936 is necessarily brief and, in some details incomplete, owing to the lack of a central state agency for the collection of data and statistics on well drilling and production. The information used in this report was compiled from the records of the several companies operating in the state.

Drilling activity in Ohio increased during 1936 as compared to the two preceding years. During the year 1157 wells were completed, as compared to 1022 wells in 1935 and 1055 wells in 1934. However, in spite of this increase in drilling activity, both oil and gas production declined for the year.

ACTIVITY BY FIELDS

Trenton Sand Field.—The Trenton sand field is located in 15 counties of northwestern Ohio, trending from Toledo on the north, south and west through Findlay into Indiana. About 40 years ago the Trenton field was one of the most important oil-producing fields in the United States, but it has declined to a position of minor importance. During the year 1936 there were 52 completions in this field—29 gas wells, 19 oil wells and 4 dry holes.

Clinton Sand Field.—The Clinton sand is by far the most important gas-producing field in the state. Production is located in small pools separated by nonproducing areas, on a band of varying width reaching from Cleveland on the north to Lawrence County on the Ohio River on the south. During 1936 a small pool of patchy character was developed in Butler township, Knox County. Seventeen wells were completed in the Clinton sand, of which 13 were gas wells and 4 were dry holes. The average initial production secured per well drilled, including dry holes, was 1,288,000 cu. ft. The average depth of the Clinton sand was 3000 feet.

A gas well was completed in lot 9 of Franklin township, Tuscarawas County. Production was found in the first Clinton sand at a depth of 4354 ft. The initial open flow after shot was 828,000 cu. ft. and the rock

Manuscript received at the office of the Institute Feb. 13, 1937.

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pressure 1325 pounds. A small gas well was completed on the Barthlome property in lot 4 of Wayne township, Tuscarawas County. Production was secured in the red Clinton sand at a depth of 4272 ft. The initial open flow was 295,000 cu. ft. after shot and the rock pressure was 1280 pounds.

During the year, 226 gas wells, 70 oil wells and 137 dry holes were completed in the Clinton sand.

Newburg Sand Field.—The Newburg sand produces gas in Summit County and both oil and gas in Cuyahoga County. Although the horizon of the Newburg sand has been penetrated in all the Clinton sand wells of eastern Ohio, it has yielded production in only a few places. During 1936 six gas wells and one oil well were completed in the Newburg sand.

Oriskany Sand Field.—Most of the production from the Oriskany sand is found in Guernsey and Tuscarawas Counties, where both oil and gas are produced. A small gas pool in the Oriskany sand has been discovered in eastern Columbiana County. Two gas wells were added to the small Oriskany gas pool in Madison and Wayne townships, Columbiana County. One well was completed on the Strudthoff property in sec. 31, Madison township, at a total depth of 4455 ft., with an initial open flow of 700,000 cu. ft. and a rock pressure of 1700 lb. The other well was completed on the Grafton farm in sec. 25, Wayne township, Columbiana County, at a total depth of 4444 ft., with an initial open flow of 700,000 cu. ft. and a rock pressure of 1700 pounds.

A wildcat test to the Oriskany sand was drilled on the Murphy farm in sec. 13, Buffalo township, Noble County. The Oriskany was encountered from 4128 to 4145 ft. The test was dry, no water being encountered. An unsuccessful wildcat test to the Oriskany sand was completed on the Comps property in sec. 9, Center township, Morgan County. The Oriskany sand was found at a depth of 3710 to 3716 ft., where water was encountered. The total depth was 3719 feet.

During November 1935 a small Oriskany gas well was secured on the Kilgore farm in sec. 21, Sugar Creek township, Stark County. During 1936 an attempt was made to extend this production by drilling two wells; one about $\frac{1}{4}$ mile to the north on the Fortney farm, and the other about $\frac{1}{2}$ mile to the southeast on the Walter farm. Both wells were dry in the Oriskany and Clinton sands.

During the year, six oil wells, seven gas wells and three dry holes were completed in the Oriskany sand.

Berea Sand Field.—Production from the Berea sand is widely scattered in many small pools in eastern Ohio. The Berea sand is second in importance as a producer of oil and gas in the state. During the year, 148 gas wells, 85 oil wells and 91 dry holes were completed in the Berea sand.

Shallow Sand Field.—There are a number of shallow sands in eastern Ohio lying above the Berea sand, which produce oil and gas in relatively

small quantities. In these shallow sands, 131 gas wells, 82 oil wells and 87 dry holes were completed during 1936.

SUMMARY OF DRILLING OPERATIONS

Table 1 shows the total number of wells drilled in Ohio during 1936. Table 2 shows the initial volumes secured on wells completed during 1936.

TABLE 1.—*Wells Drilled in Ohio during 1936*

Sand	Gas Wells		Oil Wells		Dry Holes		Total
	Number	Per Cent of All Wells	Number	Per Cent of All Wells	Number	Per Cent of All Wells	
Trenton.....	29	55.8	19	36.5	4	7.7	52
Clinton.....	226	52.2	70	16.1	137	31.7	433
Newburg.....	6	85.7	1	14.3			7
Oriskany.....	7	43.8	6	37.5	3	18.5	16
Shale.....	21	91.3			2	8.7	23
Gordon.....	2	100.0					2
Berea.....	148	45.7	85	26.2	91	28.1	324
Shallow.....	131	43.7	82	27.3	87	29.0	300
Total.....	570	49.3	263	22.7	324	28.0	1157

TABLE 2.—*Initial Volumes on Wells Completed in 1936*

Sand	Gas Wells		Oil Wells	
	Total Initial Volume, M. Cu. Ft.	Average Initial Volume, M. Cu. Ft.	Total Initial Production, Bbl.	Average Initial Production, Bbl.
Trenton.....	3,707	130	164	9
Clinton.....	200,412	882	5,245	75
Newburg.....	2,984	493	26	26
Oriskany.....	4,558	651	48	8
Shale.....	6,264	298		
Gordon.....	1,631	815		
Berea.....	29,138	197	600	7
Shallow.....	47,611	83	548	6
Total.....	296,305	519	6,631	25

SUMMARY OF PRODUCTION AND PRICES

Ohio produced 49,592,000,000 cu. ft. of gas¹ during 1935. It is estimated that 49,000,000,000 cu. ft. of gas² was produced during 1936.

¹ U. S. Bureau of Mines.

² Estimate by G. R. Hopkins, U. S. Bureau of Mines.

During 1935 Ohio produced 4,082,000 bbl. of oil. Daily average production for 1936 is estimated at 10,504 bbl., making an aggregate production of 3,834,000 bbl.³ for the year. Of this total 1,472,000 bbl. were of Pennsylvania grade, while the remaining 2,362,000 were divided between Corning and Lima grades.

TABLE 3.—*Prices for Crude Oil in Ohio in 1936*

Date	Grade	Price per Barrel
Jan. 1 to Jan. 12.....	Pennsylvania	\$1.82
Jan. 13 to Sept. 17.....	Pennsylvania	1.97
Sept. 18 to Dec. 31.....	Pennsylvania	2.12
Jan. 1 to Jan. 12.....	Corning	1.32
Jan. 13 to Sept. 17.....	Corning	1.42
Sept. 17 to Dec. 31.....	Corning	1.32
Jan. 1 to Jan. 13.....	Lodi	1.17
Jan. 14 to Dec. 31.....	Lodi	1.27
Jan. 1 to Jan. 13.....	Parma	1.22
Jan. 14 to Dec. 31.....	Parma	1.32
Jan. 1 to Jan. 9.....	Lima	1.15
Jan. 10 to Sept. 21.....	Lima	1.25
Sept. 22 to Dec. 31.....	Lima	1.15

Table 3 shows the prices paid for crude oil in Ohio during 1936 and Table 4 shows the weighted average posted price for all grades of Ohio crude oil for the past eight years.

TABLE 4.—*Weighted Average Posted Price for Ohio Crude^a*

Year	Penna.	Corning	Lima	Wooster
1929	\$3.4046	\$1.8447	\$1.70	\$1.81
1930	2.0286	1.5756	1.54	1.69
1931	1.3558	0.8261	0.90	1.02
1932	1.3755	0.9418	1.10	1.21
1933	1.3515	0.9035	0.92	0.90
1934	1.9771	1.32	1.30	Now Corning
1935	1.7113	1.32	1.15	
1936	1.9667	1.388	1.21	

^a A. E. Faine.

REPRESSURING OPERATIONS

Although the repressuring of shallow sands has been carried on for years in southeastern Ohio, only within the past few years have the possibilities of repressuring the Clinton sand been considered.

An early repressuring experiment in the Clinton sand was started by a company near New Straitsville, Ohio, in December 1933. Favorable

³ Estimate by A. E. Faine.

results were noted within a month after the injection of gas, and production was increased on a small group of wells from 120 bbl. in November 1933 to 430 bbl. per month in August 1934.

During October 1935 an operating company made an effort to stimulate the oil production of a group of wells on three adjoining leases in Hardy township, Holmes County, Ohio. There were 17 wells on the three leases. One of these was cleaned out and tubed to serve as the injection well. Two other wells were not, at the time, producing because of water troubles. There remained 14 active wells. Over a period of 13 months, during which gas was being forced into the sand slightly more than 50 per cent of the time, there was injected about 17 million cubic feet of gas. The average rate of injection during time in operation was about 74 thousand cubic feet in 24 hours. Except in a few wells the results have not been good from a production standpoint. Other factors may have influenced this, however, as there was considerable casing trouble.

In four wells, a decided improvement was noted. The monthly production of these four wells just prior to repressuring was 220 bbl. Over the period of 13 months, during repressuring, the average production was 320 bbl. The last month's production was 360 bbl. Wells equidistant from the injection well were not similarly affected. The increase was obtained from wells that lay in a general northeasterly direction and in which the oil sand was higher than in the injection well. During the same time the entire field suffered a decline in monthly production of about 13.2 per cent, compared to an increase of about 39.1 per cent in the four wells cited.

The following paragraphs are taken from a letter written by J. R. Lockett, of the Preston Oil Co.:

On Oct. 12, 1936, an operating company completed a 165-hp. double-stage compressor station near Union Furnace, Starr township, Hocking County, Ohio. Gas has been injected into either two or four Clinton wells on the Shaw and Stiers farms continuously since that time.

The station was started with a discharge pressure of 90 lb., and a daily delivery of 13 M. cu. ft. The pressure was gradually increased to an average of 200 lb., at which the average delivery was 75 M. cu. ft. The average daily return gas is 60 M. cu. ft.

Twenty-three Clinton oil wells with average depths of 2200 ft. below sea level, and an average sand thickness of 26 ft., were shut in for three weeks until their closed pressure had equalized at approximately 20 lb. The total initial daily production of the 23 wells was 3690 bbl. Their combined average daily production for the year previous to repressuring was 12 barrels.

Approximately 30 million cubic feet of gas had gone through the station to Jan. 1, 1937, which represents a circulation of approximately 15 million cubic feet. At that time, the combined daily production of the 23 wells averaged 42 barrels.

ACKNOWLEDGMENTS

The writer wishes to express his appreciation to Messrs. D. T. Ring, Geologist of The Ohio Fuel Gas Co. and the Preston Oil Co.;

J. R. Lockett, Assistant Geologist of The Ohio Fuel Gas Co. and the Preston Oil Co.; J. J. Schmidt and C. W. Gardner, of The East Ohio Gas Co.; Wilbur Stout, State Geologist of Ohio; A. E. Faine, Statistician of The Ohio-Pennsylvania Grade Oil Producers Association; G. R. Hopkins, of U. S. Bureau of Mines, and E. O. Schillhahn, of The Natural Gas Company of West Virginia, for their assistance in the preparation of this report.

Petroleum Development in Oklahoma in 1936

BY H. E. RORSCHACH* AND E. G. DAHLGREN,† MEMBERS A.I.M.E.

OIL-FIELD activities in Oklahoma made 1936 the best year since 1930. Approximately 2800 wells were completed, an increase of about 20 per cent over 1935. Purchasers' reports filed with the Corporation Commission showed a total of 200,240,252 bbl. of oil purchased from leases in 1936.

The assembly of a complete table of the oil fields of the state was not achieved, as many of the early records of operators and pipe-line companies are not complete, and data for the older fields will perhaps never be fully tabulated. Table 1 includes all of the new fields and most of the important fields of the State of Oklahoma.

The outstanding developments of the year were: the discovery of rich Wilcox-sand production in the Moore pool; the spectacular drilling campaign in the Capitol or Mansion extension in the Oklahoma City pool; the surprising extension of the Olympic pool and the Hunton lime zone in the Fitts pool; and the failure to find more Ordovician production in southern Oklahoma. Wildcat discoveries, which were on a par with 1935, resulted in the discovery of such promising pools as Billings-Wilcox, North Bethel, North Earlsboro and North Lucien. The Fitts-Upper Simpson, Edmond, Jesse, Keokuk Falls and South Burbank pools underwent considerable development.

Fitts Pool.—The Fitts area in Pontotoc County was greatly extended during the year and was the leader in drilling activity in the state. The producing limits were pushed to the east and north and the development of the Hunton lime horizon was outstanding. In the Upper Simpson zone 162 wells were completed; 137 in the Hunton lime zone and 26 in the Wilcox zone. The Oil Creek zone, a sand body below the Wilcox member, was discovered by the Magnolia-Statler No. 3 well located in the SW. $\frac{1}{4}$ of sec. 28-2N.-7E.

Moore Pool.—The Moore pool, in Cleveland County, which was opened in 1935 by the Sinclair Prairie-Franklin Community No. 1 well, surprised the oil industry when the Sinclair Prairie-Marvel No. 1 well, on Apr. 1, 1936, discovered a rich body of Wilcox sand below the distillate

Manuscript received at the office of the Institute April 30, 1937.

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TABLE 1.—Oil and Gas Production in Oklahoma

Line Number	Field, County	Age, Years to End of 1936	Area Proved, Acres				Total Oil Production Bbl.	
			Oil	Oil and Gas ^a	Gas	Total	To End of 1936	During 1935
1	Adams, Hughes	1	160			160	68,846	4,000
2	Allen, Pontotoc	23	3,000			3,000	40,077,410	2,896,745
3	Altus, Jackson	3	340			340	294,329	117,710
4	Asher-Wanette, Pottawatomie	7	675			675	6,691,721	307,838
5	Bethel, Seminole	13	570			570	1,504,039	44,402
6	Bethel, North, Seminole	1/3	300			300	16,671	None
7	Billings, Noble	21	600		60	660	y	77,160
8	Billings-Wilcox, Noble	1	60			60	141,362	None
9	Binger, Caddo	3	10			10	20,550	10,811
10	Bowlegs, Seminole	10	3,820			3,820	104,448,952	3,808,387
11	Braman, North and South, Kay	13	910	185		1,085	y	519,710
12	Britton, North, Oklahoma	2	100			100	165,002	14,687
13	Britton, South, Oklahoma	2	250			250	655,506	60,183
14	Brook, Carter	15				600	3,771,000	155,000
15	Burbank, Osage, Kay	16	22,170	0	0	22,170	190,718,000	3,057,000
16	Caldwell, Grant	8	30			30	y	3,560
17	Carr City, Seminole	9	1,060			1,060	25,004,000	2,003,000
18	Carter-Knox, Grady, Stephens	12	1,840	0	0	1,840	11,891,000	595,000
19	Cement, Caddo	20	2,325			2,325	13,156,198	615,455
20	Chandler, Lincoln	12	1,160			1,160	y	1,788,032
21	Cleveland, Pawnee	33	9,720			9,720	53,984,986	636,610
22	Crescent, Logan	4	1,010			1,010	5,669,982	1,944,972
23	Cromwell, Seminole	14	4,780	0	0	4,780	51,547,000	1,546,000
24	Cushing, Creek	25	23,528			23,528	328,268,674	4,703,028
25	Davenport, Lincoln	11		2,000		2,000	y	227,244
26	Deep Rock, Payne	12	520		80	600	y	
27	Dill, Okfuskee	3	640			640	793,890	187,526
28	Dilworth, Kay	22	5,280		2,720	8,000	y	
29	Earlsboro, Pottawatomie, Seminole	11	4,730			4,730	118,837,433	3,078,209
30	Earlsboro, East, Seminole	8	2,000			2,000	33,989,387	2,156,403
31	Earlsboro, North:							
31	Hunton, Seminole	1				160	70,441	
32	Wilcox, Seminole	1/2				200	53,132	
33	Earlsboro, South, Seminole	7	300			300	7,907,000	433,000
34	Edmond, Oklahoma	7	1,040	80	20	1,140	5,981,641	1,478,309
35	Fairfax, Osage	11	y	y	y	y	y	y
36	Fitts, Pontotoc							
36	Upper Simpson	3	y	y	y	y	24,262,540	6,714,362
37	Hunton	3	y	y	y	y	1,600,382	48,372
38	Oil Creek	1	y	y	y	y	18,660	
39	Wilcox	2	y	y	y	y	858,319	26,667
40	Fox, Carter	21	1,110		420	1,530	11,990,000	275,000
41	Fox-Simpson, Carter	2	40			40	89,964	8,964
42	Garber, Garfield	21	3,840			3,840	48,453,425	761,828
43	Gessman, Lincoln	3	110			110	y	178,927
44	Glenn, Creek	32	14,720y			14,720y	x	x
45	Graham, Carter	19	2,520		220	2,740	24,550,000	650,000
46	Gray, Pottawatomie	5				180	2,724,000	624,000
47	Grayson, Seminole	2	130			130	507,126	245,552
48	Grisso, Pottawatomie	3				80	179,200	92,200
49	Healdton, Carter	23	8,100			8,100	174,062,000	3,391,000
50	Hewitt, Carter	18	3,450	0	0	3,450	81,832,000	1,702,000
51	Hominy, Osage	17	300	0	0	300	1,881,575	42,804
52	Hominy, East, Osage	16	450	0	0	450	1,911,812	47,731
53	Hoyt, Lincoln	2	y	y	y	y	388,616	58,257
54	Hubbard, Kay	13	620	0	0	620	y	280,378
55	Hull, Logan	3	80			80	134,465	4,802
56	Jesse, Pontotoc	2	y	y	y	y	420,000	18,088
57	Joey, Okfuskee	14	0	300	10	310	y	126,945
58	Keokuk Falls, Seminole	4	900	0	0	900	3,617,000	825,000
59	Keokuk Falls-Hunton, Pottawatomie	2	y	y	y	y	57,804	6,573
60	Laffoon, Lincoln	4	60			60	695,000	281,000

^a Footnotes to column heads and explanation of symbols are given on page 291.

TABLE 1.—(Continued)

Line Number	Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
	During 1936	Daily Average during Nov. 1936	To End of 1936	During 1936	During 1936	Maximum Daily during 1936	Completed to End of 1936	During 1936		At End of 1936				
								Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas ^b	Producing Gas Only	Total Producing
1	64,846	329					4	3			4			4
2	2,812,947	4,428					y	y			278			278
3	182,500	470					y	y	6		34			34
4	193,220	486					y	y	0	y	36y	y	y	y
5	43,680	102.4					58	0	0	3y				36y
6	16,671	54					2	2			2			2
7	y	y		None			y	y	y	y			y	y
8	141,362	555					6	6				y	y	y
9	9,739	y					1	0	1	0	5		1	6
10	4,319,663	11,741					y	2	y	y	244			244
11	y	y					y	6	y	y		y	y	y
12	150,315	646					9	0	0	0		0	0	9
13	595,323	1,956					12	7	0	0	12			12
14	150,000	340												121
15	2,829,000	6,530	x	x	x	x	2,200	0	15	0	1,935	0	0	1,935
16	y	y					y	y	y	y	y	y	y	y
17	2,205,001	6,000									y	y	y	100
18	534,000	1,387	x	x	x	x	220	0	16	x	143	0	0	143
19	621,198	2,000					220	4	5	x	y	y	y	y
20	y	y					y	y	y	y	y	y	y	y
21	654,559	1,729					1,159	4	y	y	y	582	y	582
22	2,233,414	7,505					44	12	y	y	44			44
23	1,330,000	3,393	x	x	x	x	491	0	0	0	272	0	0	272
24	4,085,879	10,347					3,675	15	x	x	x	1,970	x	1,970
25	y	y					y	y	y	y	y	y	y	y
26	y	y					y	y	y	y	y	y	y	y
27	578,800	1,796					y	12	y	0	20	y	y	20
28	y	y					y	y	y	y	y	y	y	y
29	2,305,594	5,997					y	y	y	y	y	y	y	y
30	1,338,492	3,620					y	y	y	y	y	y	y	y
31	70,441	355					4	4						4
32	53,132	335					5	5						5
33	226,000	834					30	None	?	None				15
34	4,386,440	13,493					73	37	0	1	71	1		72
35	y	y					y	y	y	y	y	y	y	y
36	17,385,236	51,622					394	162	0	0	394			394
37	1,543,651	7,941						137						
38	13,660	339					1	1	0	0	1	0	0	1
39	831,652	3,390					28	24	0	0	28	0	0	28
40	350,000	1,130	80,500	3,000	2,500	y	144	2	5	0	98	0	33	131
41	81,000	500					1	0	0	0	1	0	0	1
42	708,038	3,034	0	0	0	0	873	1	0	x	x	582	x	582
43	y	y					y	y	y	y	y	y	y	y
44	x	x					y	y	y	y	y	y	y	y
45	600,000	1,550	48,200	1,200	1,000	0	322	0	1	0	300	0	17	317
46	560,000	1,440						y	y	y	y	y	y	22
47	261,574	553					12							12
48	66,200	140					3							3
49	3,449,000	9,579	x	x	x	x	2,201	39	17	x	1,891	0	0	1,891
50	1,644,000	4,407	x	x	x	x	902	4	16	x	796	0	0	796
51	30,499	78					y	None	None	y	y	y	y	y
52	28,423	82					y	1	None	y	y	y	y	y
53	330,359	1,226												
54	y	y					y	y	y	y	y	y	y	y
55	33,711	y					2	0	0	0	2			2
56	401,912	1,960					18	17	0	0	18	y	y	18
57	y	y					y	y	y	y	y	y	y	y
58	2,089,000	6,167	0	0	0	0	100	52	0	0	100	0	0	100
59	51,231	286					y	y	y	y	y	y	y	y
60	320,000	y					3	1			4			4

TABLE 1.—(Continued)

Line Number	Depth, Average in Feet		Oil Production Methods at End of 1936						Pressure, Lb. per Sq. In. ^d			Character of Oil, Approx. Average during 1936					
	Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells					Injection into Reservoir ^c	Average at End of		Gravity A.P.I. at 60° F.						
			Flowing	Pumping	Gas-lift	Air-lift	Miscellaneous		Initial	1935	1936	Maximum	Minimum	Weighted Average	Sulphur, Per Cent	Base ^e	
1	4,050	4,030	3	1					e1,500						40		M
2	2,600	y		278					y	y	y				30		y
3	1,500	y		34				y	y	y	y				43		y
4	y	y	y	y	y	y	y	y	y	y	y				43		y
5	3,297	3,270	0	34	2							40	32	36	0.2	M	
6	3,620	3,600	2						1,300	None	1,300			40		M	
7	2,100	2,000	y	y	y	y	y	y	y	y	y			41		y	
8	4,258	y	6						e1,740		e1,720					y	
9	11,230	11,195		1					y	y	y			41		y	
10	4,300	4,100		244					y	y	y			40		y	
11	3,402	1,934	y	y	y	y	y	y	y	y	y			41		y	
12	6,706	6,547	y	y	y	y	y	y	2,000	2,000	y			43		y	
13	6,749	6,609	y	y	y	y	y	y	2,200	2,200	y			43		y	
14	2,100	Var.		121								38	25	35	0.8	A	
15	2,700-3,000	x	0	1,935	0	0	0	0	x	x	x	x	x	38	x	P	
16	4,785	4,779	y	y	y	y	y	y	y	y	y			44		y	
17	4,205	4,180		100					e320	e90	y	y	y	40	0.3	M	
18	1,720-2,100	x	0	143	0	0	0	0	x	x	x	38	26	35		x	
19	2,800	x	y	y	y	y	y	y	y	y	y			35		y	
20	y	y	y	y	y	y	y	y	y	y	y			40		y	
21	2,400	1,700	y	y	y	y	y	y	y	y	y			37		y	
22	6,219	6,190	37	5	2				e2,920	e1,741	y			42		y	
23	3,400	x	0	272	0	0	0	0	x	x	x			35	x	x	
24	2,800	2,200	y	1,970	y	y	y	y	y	y	y			40		y	
25	3,440	3,390	y	y	y	y	y	y	y	y	y			46		y	
26	4,250	4,200	y	y	y	y	y	y	y	y	y	y	y	y		y	
27	3,930	3,900	y	y	y	y	y	y	y	y	y			40		y	
28	Various	y	y	y	y	y	y	y	y	y	y			40		y	
29	4,300	y	y	y	y	y	y	y	y	y	y			39	y	y	
30	y	y	y	y	y	y	y	y	y	y	y			39		y	
31	4,440	4,420	3	1					e1,940	None	e1,900			40		M	
32	4,650	4,640		6					e1,385	None	e1,365			31		M	
33	4,225	4,200		15					e 550	None	e 350			40	0.3	M	
34	y	y	70	1	0	0	0	0	e2,900	e2,640	e1,900	52	38	39		P	
35	2,800	2,750	y	y	y	y	y	y	y	y	y			38		y	
36	4,325	x	y	y	y	y	y		e1,980		e1,100			39		y	
37	3,700	3,350	y	y	y	y	y		y		e500 to 1,650			39		y	
38	4,656	4,547	0	1	0	0	0	0	x	x	x			37.9		y	
39	4,415	y	y	y	y	y	y		e1,850		e1,500						
40	2,500	2,200		98				0	500-2,900	y	y	46	27	y		M	
41	8,105	6,694	1	0	0	0	0	0	x	x	x			30	x	x	
42	4,200	1,100	y	y	y	y	y	y	y	y	y			44		y	
43	3,065	3,050	y	y	y	y	y	y	y	y	y			45		y	
44	1,575	1,475	y	y	y	y	y	y	y	y	y			35	x	P	
45	2,800	2,400	0	317	0	0	0	0	750	y	y	36	26	32		M	
46	3,475	2,500		22					e1,440	x	x			40	x	M	
47	3,850	3,750		12					y	y	y			40		y	
48	4,050	4,030		3										35	x	M	
49	750-1,900	y	0	1,891	0	0	0	0	x	x	x	32	29	31		x	
50	1,500-2,000	y	0	796	0	0	0	0	x	x	x	36	31	34		x	
51	2,685	2,625	y	y	y	y	y	y	y	y	y			37		y	
52	2,210	2,160	y	y	y	y	y	y	y	y	y			34		y	
53	5,100	y	y	y	y	y	y	y	y	y	y			41		y	
54	y	y	y	y	y	y	y	y	y	y	y			39		y	
55	4,800	y	1	1					y	y	y			42		y	
56	4,633	4,621	18	0	0	0	0		y	y	y			41		y	
57	3,650	3,600	y	y	y	y	y		y	y	y			41		y	
58	4,100	4,550	88	12	0	0	0	2G	1,828	1,600	1,400	41.6	39.4	40		x	
59	4,152	4,117	y	y	y	y	y		y	y	y			41		y	
60	4,275	4,190		3					e1,872		e 275			22.5	x	A	

TABLE 1.—(Continued)

Line Number	Character of Gas, Approx. Average during 1936		Producing Rock						Number of Dry and/or Near-dry Holes to End of 1936	Deepest Zone Tested to End of 1936		
			Name	Age ¹	Character ²	Porosity ³	Net Thickness, Average in Feet	Structure ⁴		Name	Depth of Hole, Feet	
	B.t.u. per Cu. Ft.	Gals. Gasoline per M. Cu. Ft.										
1			Hunton-Misener	Sil-Mis	Lime	P	15	A	0	Wilcox sand	4,317	
2			Cromwell, Wilcox	Pen-Ord	S	Por	y	AF	66	y		
3			Granite wash	Pen	S	Por	30	D	y	Granite wash	3,003	
4			y	y	y	y	y	y	y	y		
5			Booth	Pen	y	Silty	27 y	ML	2	Wilcox sand	4,411	
6			Cromwell	Pen	S	Por	20	A	y	Cromwell		
7			Hoover	Pen	S	Per	50	A	y	Arbuckle	5,031	
8			Wilcox	Ord	S	Per	20	A	y	Arbuckle	5,031	
9			Binger	Pen	S	Per	y	y	y			
10			Wilcox or Simpson	Ord	S	Por	30	A	y	2nd Wilcox	4,390	
11			Various	Pen-Ord	SL	Por	y	A	y	Arbuckle	3,553	
12			Simpson	Ord	D, L	Por	y	A	y	y		
13			Simpson	Ord	D, L	Por	50	AF	3	2nd Wilcox	6,931	
14		1.25	Various	Pen	S	Por	60	AF	46	Ordovician lime	3,000	
15	x	x	Burbank	Pen	S	Por	60	ML	75	Granite	4,240	
16	x	x	Wilcox	Ord	S	Por	6	A	1	Wilcox	4,785	
17		2.0	Hunton-Wilcox	Pen-Ord	L-S	Por	x	A	13	Wilcox	4,210	
18	x	x	Various	Pen	S	15-20	15	AF	64	Lower Deese	8,963	
19			Caddo, Fortuna	Per-Pen	S	y	y	y	y	Pennsylvanian	10,079	
20			Wilcox	Ord	S	Por	x	A	y	y		
21			Cleveland-Bartlesville	Pen	S	Por	y	y	y	Arbuckle L	y	
22			Layton-2nd Wilcox	Pen-Ord	S	23	y	AF	y	y		
23	x	x	Cromwell	Pen	S	Por	x	AF	55	Wilcox	4,226	
24			Numerous Horizons	Pen-Ord	S, L	Por	x	AF	x	Granite	3,750	
25			Prue	Pen	S	Por	50	ML	18	Wilcox	4,666	
26			Wilcox, Bartlesville	Pen-Ord	S	Por	50	A	3	Arbuckle	4,542	
27			Hunton-Cromwell	Sil, Pen	S, L	Por	30	y	y	Wilcox	4,225	
28			Various	Per, Pen, Ord	S, SL	Por	y	A	y	Arbuckle	4,243	
29			Earlsboro-Wilcox	Pen-Ord	y	y	y	y	97	y		
30			y	y	y	y	y	y	y	y		
31			Hunton	Sil	L			A		Wilcox	4,680	
32			Wilcox	Ord	S	Por	10	A	None	Wilcox	4,650	
33			Wilcox	Ord	S	Por	25	A	4	Wilcox	4,225	
34			Wilcox	Ord	y	AF	y	A	4	Arbuckle	7,000	
35			Burbank	Pen	S	20-25	y	ML	y	y		
36			Bromide, McLish	Ord	S	Por	y	AF	y	Arbuckle	y	
37			Hunton	Sil	L	250	AF	AF		Arbuckle	y	
38			Oil Creek	Ord	S	Por	10	AF		Arbuckle	y	
39			Wilcox	Ord	S	Por	y	AF		Arbuckle	y	
40			Deese	Pen	S	30	y	A	27	McLish or Oil Creek	8,105	
41	x	x	Simpson	Ord	S	x	y	AF	1	Simpson	8,105	
42			Various	Per-Pen-Ord	S, L	Por	y	AF	y	y		
43			Cleveland	Pen	S	Por	y	M	4	Wilcox	5,002	
44			Glenn, Wilcox	Pen-Ord	S	Por	y	ML	y	Arbuckle	2,964	
45	y	1.0	Deese	Lower Pen	S	28-30	45-70	A	40	Dornick Hills	5,108	
46	x	x	Wilcox	Ord	S	Por	25	A	N.S.	1	Wilcox	3,500
47			Hunton, Simpson dolomite	Sil, Ord	SL	y	y	y	y	y		
48	x	x	Hunton	Sil	L	x	x	A		Wilcox	4,860	
49	x	x	Various	Pen-Ord	SL	Por	x	AF	173	Arbuckle	x	
50	x	x	Hoxbar	Pen	S	15-20	50	AF	77	Arbuckle	x	
51			Burgen-Siliceous lime	Ord	S, Dol	x	50	A	y	Arbuckle	3,206	
52			Bartlesville	Pen	S	x	y	A	y	Arbuckle	2,857	
53			1st Wilcox	Ord	S	Por	y	y	y	y		
54			Various	Pen-Ord	SL	Por	y	AF	y	Arbuckle	3,761	
55	y	y	Layton	Pen	S	Por	y	y	y	y		
56			McLish	Ord	S	Por	y	AF	y	y		
57	y	2.2	Wilcox	Ord	S	x	50	D	y	Wilcox	3,700	
58	y	y	Misener-Hunton	Mis, Sil	SL	y	15-20	A	14	Wilcox	4,483	
59			Hunton	Sil	L	y	y	y	y	y		
60			Wilcox	Ord	S	Por	x	A	0	Wilcox	4,267	

TABLE 1.—(Continued)

Line Number	Field, County	Age, Years to End of 1936	Area Proved, Acres				Total Oil Production, Bbl.	
			Oil	Oil and Gas ^a	Gas	Total	To End of 1936	During 1935
61	Langston, Logan.....	3	160			160	227,000	99,000
62	Lincreek, Lincoln-Creek.....	21	160			160	y	126,519
63	Little River, Seminole.....	10	4,900			4,900	106,616,430	5,088,639
64	Little River, East, Seminole.....	9	640			640	15,655,463	302,097
65	Lovell, West, Logan.....	1	20			20	39,388	
	Lucien, Noble.....							
66	East: Misener.....	2	110			10	73,362	38,744
67	Viola.....	3	10			10	88,260	36,563
68	North.....	1	10			10	10,436	
69	Lucien.....	4	2,660			2,660	11,284,026	3,915,000
70	Marshall, Logan.....	10	700	240		940	y	273,746
71	Maud, Pottawatomie-Seminole.....	8	1,440			1,440	10,848,000	416,000
72	Meeker, Lincoln.....	2	10			10	8,052	None
73	Mission, Seminole.....	10	y	y	y	y		1,126,337
74	Moore, Cleveland.....	2	800			800	690,130	249,082
75	Naval Reserve, Osage.....	9	2,720		160	2,880	9,552,128	3,066,914
76	Nicomia Park, Oklahoma.....	7	y	y	y	y	496,867	25,585
	Oklahoma City, Oklahoma.....							
77	Wilcox.....	7	6,900			6,900	240,778,299	43,997,824
78	Lower Simpson.....	8	10,000			10,000	89,604,131	8,196,061
79	Cleveland.....	8	80			80	1,365,215	607,588
80	Arbuckle.....	8	570	1,020	0	1,590	17,501,354	48,711
81	Highley.....	4	10			10	201,186	52,024
82	Total.....		17,560	1,020		28,680	349,450,185	45,525,208
83	Olympic, Hughes-Okfuskee.....	3	3,500			3,500	2,913,306	117,898
84	Otoe City, Noble.....	6	10			10	y	4,870
85	Otatott, Kay.....	19	3,300			3,300	y	228,441
86	Papoose, Hughes, Okfuskee.....	13	2,400			2,400	23,145,000	446,000
87	Pettit, Osage.....	17	380			380	y	40,591
88	Polo, Noble.....	3	390			390	2,304,759	1,160,000
89	Ponca City, Kay.....	26	1,670			1,670	y	112,978
90	Ripley, North, Payne.....	9		90		90	y	y
91	Robberson, Garvin.....	16	1,480		320	1,800	12,370,000	400,000
92	St. Louis, Pottawatomie-Seminole.....	11	7,300			7,300	103,800,765	8,138,521
93	Sasakwa, Seminole.....	9	560			560	7,435,965	292,015
94	East, Wilcox.....	2	y	y	y	y	322,140	18,657
95	Townsite.....	4	120			120	1,553,331	536,798
96	Searight.....	11	1,300			1,300	31,561,337	1,047,013
97	Searight, North, Seminole.....	3	310			310	1,291,489	336,158
98	Seminole City, Seminole.....	11	3,640			3,640	115,262,617	3,993,448
99	Seminole, East, Seminole.....	11	510			510	5,546,271	441,008
100	Seminole, West, Seminole.....	7	260			260	9,640,000	1,260,000
101	Shawnee, Pottawatomie.....	3	500			500	357,749	120,136
102	Sholom Alechem, Carter, Stephens.....	13	4,180		220	4,400	31,490,000	1,417,000
103	Stillwater, Payne.....	2	120			120	309,000	39,000
104	Tatums, Carter.....	10	2,230	0	0	2,230	14,580,000	1,743,000
105	Thomas, Kay.....	13	140			140	y	101,119
106	Tipton, Jackson.....	2	y	y	y	y	y	20,117
107	Tipton-Arbuckle, Jackson.....	1	280			280	211,180	
108	Tonkawa, Kay, Noble.....	16	2,300			2,300	y	1,203,417
109	Tussy, Garvin.....	4	360			360	503,436	
110	Vernon, Kay.....	13	920			920	y	280,378
111	Vines, Murray.....	17	y	y	y	y	y	
112	Watchorn, Pawnee.....	21	0	320	0	320	y	116,792
113	Wewoka and Wewoka Townsite, Seminole.....	14	2,150			2,150	y	1,323,796
114	Wheeler, Carter.....	21	540	0	160	700	1,177,000	38,000
115	Wilsetta, Lincoln.....	3	200			200	398,000	112,000
116	Zimmerman, Lincoln.....	1	10			10	y	
117	Manathon, Noble.....	2	y	y	y	y	73,835	42,175

TABLE 1.—(Continued)

Line Number	Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
	During 1936	Daily Average during Nov. 1936	To End of 1936	During 1935	During 1936	Maximum Daily during 1936	Completed to End of 1936	During 1936		At End of 1936				
								Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas ^b	Producing Gas Only	Total Producing
61	55,000	130					3							3
62	y	y					y	y	y	y	y	y	y	y
63	4,617,456	11,878					y	y	y	y	y	y	y	y
64	398,586	1,110					y	y	y	y	y	y	y	y
65	39,388	103					2	2	1		2			2
66	36,618	100					1	0	0	0	1			1
67	36,472	96					1	0	0	0	1			1
68	10,436	0					1	1	0	0	1			1
69	4,401,926	12,268					91	13	0	0	91			91
70	y	y					y	y	y	y	y	y	y	y
71	340,000	900										y	y	70
72	None	None					1	0	0	0	0	0	0	0
73	888,860	2,187					y	y	0	0	y	y	y	y
74	441,048	2,173					11	10	0	0	11	0	0	11
75	2,708,014	6,924					y	60	None	y	y	y	y	y
76	20,998	57					2	0	0	0	2	0	0	2
77	42,688,205	115,625					y	y	y	y	661			661
78	8,044,564	24,587					y	y	y	y	319			319
79	537,751	1,119					y	y	y	y	26			26
80	80,202	273					y	0	y	y	33			33
81	45,768	108					y	0	y	y	1			1
82	51,396,490	141,712					y	y	y	y	1,040			1,040
83	2,795,408	10,164					218	145	12		218			218
84	y	y					y	y						
85	y	y					y	y	y	y	y	y	y	y
86	350,000	800												80
87	y	y												
88	1,041,611	2,101					36	1	1			36		36
89	y	y					y	y	y	y	y	y	y	y
90	y	y					y	y	y	y	y	y	y	y
91	500,000	1,500	0	0	0	0	273	0	5	0	198	0	12	210
92	8,343,313	21,918					y	y	y	y	y	y	y	y
93	426,292	1,058					y	y	y	y	y	y	y	y
94	303,483	1,011					y	y	y	y	y	y	y	y
95	308,727	626					y	y	y	y	y	y	y	y
96	829,194	2,208					y	y	y	y	y	y	y	y
97	908,337	2,628					y	y	y	y	y	y	y	y
98	3,760,630	9,965					y	y	y	y	y	y	y	y
99	1,096,271	3,571					28	4	y	y	y	y	y	27
100	2,048,000	4,665									y	y	y	
101	209,510	648												
102	1,273,000	3,280	15,200	0	0	0	362	0	0	0	323		15	338
103	270,000	550					6	2		0	0	0	0	6
104	1,280,000	3,300	0	0	0	0	205	3	1	0	203	0	0	203
105	y	y												
106	y	y												
107	211,180	1,173												
108	y	y						15	4	y	30	y	y	y
109	231,000	1,700					y	y	y	y	y	y	y	y
110	y	y					y	y	y	y	y	y	y	y
111	y	y					y	y	y	y	y	y	y	y
112	y	y					y	y	y	y	y	y	y	y
113							y	y	y	y	y	y	y	y
114	39,000	130	500	0	0	0	105	3	0	0	73	0	0	73
115	145,000	400					y	y	y	y	4	y	y	y
116	y	y					1	1	0	0	1			1
117	31,660	66					1	0	0	0	1	0	0	1

TABLE 1.—(Continued)

Line Number	Depth, Average in Feet		Oil Production Methods at End of 1936						Pressure, Lb. per Sq. In. ^s		Character of Oil, Approx. Average during 1936					
	Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells					Injection into Reservoir	Initial	Average at End of		Gravity A.P.I. at 60° F.			Sulphur, Per Cent	Base*
			Flowing	Pumping	Gas-lift	Air-lift	Miscellaneous			1935	1936	Maximum	Minimum	Weighted Average		
61	5,145	5,100		3					z	e1,031	y	z	z	40	z	M
62	3,700	y	y	y	y	y	y	y	y	y	y			32	y	y
63	y	y	y	y	y	y	y	y	y	y	y			39	y	y
64	y	y	y	y	y	y	y	y	y	y	y			36	y	y
65	6,150	y	y	y	y	y	y	y	y	y	y			40	y	y
66	4,982	4,972	1						y	y	y	y	y	y	y	y
67	4,983	4,970	1						y	y	y	y	y	y	y	y
68	5,389	5,373	1	0	0	0	0	0	e2,200	2,200	y	y	y	y	y	y
69	5,200	5,000	55	26	10	0	0	0	y	y	y			42	y	y
70	6,039	3,900	y	y	y	y	y	y	1,950	y	y			40	y	y
71	4,140	4,130	70						e1,000y	50y	50y			39	0.35	M
72	5,461	5,455	Pool abandoned					0	y	0	0	y	y	32	y	y
73	y	y		y	y	y	y	y	y	y	y			39	y	y
74	7,291	7,245	11	0	0	0	0	0	y	y	y			47	y	y
75	2,650	2,590	y	y	y	y	y	y	y	y	y	39	37	39	y	y
76	6,200	6,140	0	2	0	0	0	0	y	y	y			39	y	P
77	6,500	6,350	y	y	y	y	y	y	e2,600	y	y			39	y	y
78	6,500	6,200	y	y	y	y	y	y	e2,660	y	y			39	y	y
79	5,850	y	y	y	y	y	y	y	y	y	y			40	y	y
80	6,500	6,100	y	y	y	y	y	y	y	y	y					
81	6,659	6,650	y	y	y	y	y	y	1,000	y	y					
82	y	y	y	y	y	y	y	y								
83	1,750	1,680	y	y	y	y	y	y	y	y	y	y	y	34	y	y
84	3,310	3,280														
85	3,475	2,400	y	y	y	y	y	y	y	y	y			39	y	y
86	3,320	3,310		80										37	0.1	M
87	y	y												36		
88	4,900	4,823	1	34			1		y	y	y	44	40			P
89	y	y	y	y	y	y	y	y	y	y	y			38	y	y
90	4,259	4,199	y	y	y	y	y	y	y	y	y			43	y	y
91	1,400	1,300	None	210	0	0	0		600	y	y	33	25	28		M
92	y	y	y	y	y	y	y	y	y	y	y			39	y	y
93	y	y	y	y	y	y	y	y	y	y	y			37	y	y
94	4,136	y	y	y	y	y	y	y	y	y	y			37	y	y
95	y	y	y	y	y	y	y	y	y	y	y			37	y	y
96	y	y	y	y	y	y	y	y	y	y	y			38	y	y
97	4,600	y	y	y	y	y	y	y	y	y	y			32	y	y
98	4,150	4,100	y	y	y	y	y	y	y	y	y			39	y	y
99	y	y	y	y	y	y	y	y	y	y	y			39	y	y
100	4,115	4,085		27					e 500	e 75	e 50			40		M
101	4,457	y												34		
102	3,300	2,900	0	338	10	0	0	0	760	0	0	35	27	32	0	M
103	4,306	4,300		6					e1,700	e1,500	e 950	40	40	40		M
104	2,400	2,250	0	All	0	0	0	0	500	0	0	31	21	28	0	M
105	y	y	y	y	y	y	y		y	y	y			41		
106	2,635	2,595	y	y	y	y	y		y	y	y			40		
107	y	y	y	y	y	y	y		y	y	y			40		
108	4,216	1,819	y	y	y	y	y		y	y	y			42		
109	2,700	2,200	y	y	y	y	y		y	y	y			26		
110	y	y	y	y	y	y	y		y	y	y			40		
111	y	y	y	y	y	y	y		y	y	y			y		
	Wilcox															
	4,100															
	Layton															
112	2,750	z	y	y	y	y	y		y	y	y			41		
	y	y	y	y	y	y	y		y	y	y	y	y	y		
113	4,100	3,200	y	y	y	y	y		y	y	y			38		
114	1,050	1,000	0	All	0	0	0	0	300	0	0	21	17	26	0	M
115	4,290	4,240		4	y	y	y		e1,977	y	y	40	39	39.7	0	M
116	4,358	4,338	0	1	0	0	0	0	y	y	y			y		
117	4,480	4,446	0	1	0	0	0	0	1,665	z	z	y	y	y	y	y

TABLE 1.—(Continued)

Line Number	Character of Gas, Approx. Average during 1936			Producing Rock						Deepest Zone Tested to End of 1936	Depth of Hole, Feet
	B.t.u. per Cu. Ft.	Gas. Gals. line per M. Cu. Ft.	Name	Age ^f	Character ^g	Porosity ^h	Net Thickness, Average in Feet	Structure ⁱ	Number of Dry and/or Near-dry Holes to End of 1936	Name	
61	z	z	Wilcox	Ord	S	Por	z	A	0	Wilcox	5,246
62	y	y	Wilcox	Ord	S	Por	y	y	y	y	y
63			y		S	Por	y	y	y	y	y
64			Cromwell-Wilcox	Pen, Ord	S	Por	y	y	y	y	y
65			Wilcox	Ord	S	Por	y	y	y	y	y
66			Misener	Mis	S	Por	y	y	y	y	y
67			Viola	Ord	L	Por	y	y	y	y	y
68			Wilcox	Ord	L-S	Por	y	y	y	y	y
69			Wilcox	Ord	L-S	Por	y	y	y	y	y
70			Various	Pen, Ord	S	Por	y	y	y	y	y
71	x	x	Misener-Hunton	Mis-Sil	S-L	Por	10	A	33	Wilcox	4,330
72			Wilcox	Ord	S	Por	6	y	y	y	y
73			y	Ord	S	Por	y	A	y	y	y
74			2nd Wilcox	Ord	S	Por	y	A	y	y	y
75	y	y	Burbank	Pen	S	x	y	y	y	y	y
76			Tropex	Pen	S	Por	12	ML	3	Wilcox	6,404
77			Wilcox	Ord	S	22.5	y	y	y	y	y
78			Lower Simpson	Ord	S	Por	y	y	y	y	y
79			Cleveland	Pen	S	Por	y	y	y	y	y
80			Arbuckle	Cam, Ord	L	Cav	y	y	y	y	y
81			Misener	Pen	S	Por	y	y	y	y	y
82							y	y	y	y	y
83	y	y	Senora-Colvin	Pen	S	Por	y	y	y	Wilcox	y
84			Layton	Pen	S	Por	x	y	y	y	y
85			Stalnaker-Oswego	Pen	SL	y	y	y	y	y	y
86	x	1	Cromwell	Pen	S	Por	10	A	x	Wilcox	x
87			Various	Pen-Ord	LS	Por	y	A	y	y	y
88	x	x	Simpson dol., sand	Ord	SD	Por	45	A	5	2nd Wilcox	6,446
89			Various	Per-Mis-Ord	S	y	y	y	y	Granite Basement	y
90			Wilcox	Ord	S	Por	y	y	y	y	y
91	0	1	Pontotoc-Simpson	Per-Ord	SL	y	y	A & AV	37	Ordovician	4,275
92	y	y	Hunton-Simpson	Sil-Ord	LS	Por	y	y	y	y	y
93	y	y	Cromwell-Wilcox	Pen-Ord	S	Por	y	y	y	y	y
94	y	y	Wilcox	Ord	S	Por	y	y	y	y	y
95	y	y	Wilcox	Ord	S	Por	y	y	y	y	y
96	y	y	Hunton-Wilcox	Sil-Ord	SL	Por	y	y	y	y	y
97	y	y	Wilcox	Ord	S	y	y	y	y	y	y
98	y	y	Wilcox (Simpson)	Ord	S	Por	y	y	y	y	y
99	y	y	y	y	y	y	y	y	y	y	y
100		4.8	Wilcox	Ord	S	P	30	A	1	Wilcox	4,150
101			Earlsboro	Pen	S	Por	y	y	y	y	y
102	0	0	Deese	Pen	S	30	40	A	54	Dornick Hills	5,115
103			Deese	Ord	S	Por	6	A	0	Wilcox	4,306
104			Deese-Dornick Hills	Pen	S	30	60	AM DL	36	Dornick Hills or Spry	4,250
105			Various	Pen, Mis, Ord	SL	Por	y	x	y	y	y
106			Not determined	?	L	Por	y	x	y	y	y
107			y	y	S	y	y	y	y	y	y
108			Various	Pen-Ord	S	Por	y	x	y	y	y
109			Deese	Pen	S	Por	y	A	y	y	y
110			Stalnaker	Mis	S	Por	y	x	y	y	y
111			Simpson	Ord	S	Por	y	x	y	y	y
112			Wilcox-Layton	Ord-Pen	S	Por	y	y	y	y	y
113			y	Pen, Sil, Ord	SL	Por	y	y	y	y	y
114			Cromwell-Hunton-Wilcox	Ord	S	y		A	15	Penn	3,900
115	1,440	3	Pontotoc	Upper Pen	S						
116			Hunton	Sil	L	x	50	A	0	Wilcox	4,520
117	x	x	Wilcox	Sil Ord	L S	Por	20	y	y	Wilcox	4,518

pay found in the discovery well. Later the discovery well was deepened from 7291 ft. to 7318 ft., for a 35,000-bbl. producer. The Anderson-Prichard State No. 1 well in the north part of the pool was completed in September with a gas volume of over 200,000,000 ft. Ten wells were completed during the year. The close of the year found the pool practically defined on all sides except to the north, where further development will be made.

Oklahoma City.—The Oklahoma City field, which was given a revival in October, 1935, with the discovery of Wilcox production in the Capitol extension area, carried on a spectacular drilling campaign when a city election threw open previously restricted areas in the north part of the pool. Salt water soon defined the north part of the pool. Initial bottom-hole pressures in the extension area were approximately 500 lb. as compared to the 2600-lb. estimated original bottom-hole pressure in the south part of the field. Several producers were completed near the east fault in the Simpson below Wilcox series. Practically all of the wells in the Capitol extension area were completed with pressure drilling equipment. At the close of the year several drilling wells were seeking production in the Simpson dolomite above Wilcox horizon in the north part of the extension. Hydraulic pumping equipment was installed in 15 wells during the year. Submersible electrical centrifugal pumps in combination with gas-lift proved successful in lifting large quantities of oil. Many exhausted oil wells were plugged back to make gas wells in the Oswego, Layton, Prue, Oolitic, Hoover and Tonkawa horizons in the old part of the field.

Edmond Pool.—Thirty-seven wells were completed in the Edmond pool during the year. The Blackstock Oil Company's Tegtmeier No. 1 in the NE. $\frac{1}{4}$ of the NE. $\frac{1}{4}$ of the SE. $\frac{1}{4}$ of sec. 36-14N.-4W. extended the pool to the west with an 8200-bbl. well in October. Many inside locations were drilled. Shooting helped many wells. Water encroachment menaced the north end of field.

Crescent Pool.—The Crescent pool in Logan County surprised everyone in 1936 with large producers from wells drilled to the second Wilcox sand. The Continental Oil Company's McConnell No. 2 well, in the SE. $\frac{1}{4}$ of sec. 28-17N.-4W. produced only 250 bbl. per hour in the first Wilcox, but made 1685 bbl. in the first hour from second Wilcox. Several old wells were deepened from the first Wilcox. Twelve wells were completed during the year. Operations at the close of the year were concentrated on the west edge.

Jesse Pool.—The Jesse pool was developed further in 1936 with 17 producers. The discovery well, the Continental McCarty No. 1, was deepened from 4641 to 4693 ft. and made 946 bbl. in one hour.

Greater Seminole Area.—The Greater Seminole area remained active during the year. Production increased in many pools, owing to higher

allowables. The South Keokuk Falls and Keokuk Falls pools were merged when drilling operations connected the areas. Several excellent wells were completed in the East Seminole pool. The Allen pool was revived with several good Wilcox wells on the west side of the pool.

TABLE 2.—*Summary of Drilling Operations in Oklahoma*

County	Location			Total Depth, Ft.	Deepest Horizon Tested	Drilled by	Initial Production per Day	
	Sec.	Twp.	Rge.				Oil, U. S. Bbl.	Gas, Millions Cu. Ft.
	Survey	Lat.	Long.					
1 Stephens...	15	1 S.	4 W.	415	Undetermined	M. T. Cummings	3	1.5
2 Payne....	34	18 N.	5 E.	3090	Prue	Deep Rock Oil Co.		15
3 Seminole...	3	8 N.	8 E.	3374	Cromwell	Van Deventer		15.887
4 Lincoln...	28	14 N.	5 E.	P.B. 3900 4188	Skinner	Texas Company		1.9
5 Okfuskee...	21	13 N.	7 E.	4143	Hunton	Wm. J. Sherry et al.		10
6 Kiowa....	34	7 N.	17 W.	P.B. 960 1547	Undetermined	W. C. Adams et al.	25	
7 Jackson...	32	1 N.	19 W.	2654	Cisco	Gulf Oil Corporation	2100	
8 Carter....	2	4 S.	2 W.	1016	Undetermined	Schermerhorn Oil	6	
9 Hughes....	11	8 N.	9 E.	3454	Booch	M. H. Halsey		7
10 Kiowa....	2	6 N.	17 W.	458	Undetermined	Burris & Moore	5	
11 Lincoln...	35	15 N.	2 E.	5243	Wilcox	Stanolind	25	3
12 Logan....	20	18 N.	4 W.	6145	Wilcox	Stanolind	1045	40
13 Logan....	23	15 N.	3 W.	6204	Simpson dolomite	Sinclair Prairie	65 ¹	
14 Comanch...	21	3 N.	10 W.	P.B. 1813 4167		G. L. Pace		1
15 Pontotoc...	30	5 N.	4 E.	1946	Shale	Mid-Texas	100	
16 Oklahoma...	17	13 N.	3 W.	6695	Wilcox	Sinclair Prairie	240	22.5
17 Caddo....	2	5 N.?	9 W.	6367	Brown sand	Marathon	1077	71
18 Carter....	27	2 S.	3 W.	8105	Simpson	Carter et al.	3309	
19 Seminole...	35	11 N.	5 E.	4628	Wilcox	Amerada Petr. Corp.	350 (21 hr.)	Not known
20 Seminole...	3	10 N.	5 E.	4438	Hunton	Amerada Petr. Corp.	1036	Not known
21 Caddo....	35	6	10 W.	6573	Unknown	Magnolia		15.23
22 Seminole...	32	9 N.	8 E.	1900	Calvin	Imperial Drill, Co.		6
23 Carter....	6	5 S.	1 W.	4191	Oil Creek	Texas Company	18	
24 McIntosh...	9	19	14	4525	Wilcox-Gilcrease	I. T. I. O.		1
25 Pontotoc...	16	5	6	P.B. 2731 3016	Hunton	Pioneer O. & G. Co.	Inches 7	
26 Noble....	31	21	2 W.	P.B. 2760 5389	Wilcox	Shell et al.	1815	4
27 Garvin...	5	4	3	3018	Hunton	C. E. Carter et al.	143	
28 Lincoln...	10	12	5	4358	Hunton	Amerada Petr. Corp.	320	
29 Lincoln...	21	17	3		Unknown	Skelly Oil Co.		
30 Lincoln...	28	17	5		Unknown	Fleetborn		
31 Hughes...	11	7	8	1842	Senora	Olympic Oil	35	
32 Payne....	29	19	5	3802	Wilcox	Amerada Petr. Corp.	195	
33 Seminole...	36	10	7	3638	Cromwell	Amerada Petr. Corp.	235	30
34 Noble....	21	23 N.	2 W.	4258	Wilcox	Phillips	Barrels 661 in 28 min.	5.5
35 Pontotoc...	28	2 N.	7 E.		Oil Creek	Magnolia		

¹ By heads.

Olympic Pool.—The Olympic pool was the most outstanding shallow pool in the state during the year. The pool, which was opened in Hughes County, was extended into Okfuskee and Seminole Counties by a steady northward march; 145 wells were completed during the year from the Senora sand of Pennsylvanian age. The sand is found at around 1700 to 1800 ft. At the close of the year the pool was being extended towards the North Olympic pool, which was discovered in the early part of 1936.

Wildcatting.—Wildcatting in general was disappointing during the year. Eighty per cent of the strictly wildcat tests were failures. Deep

tests were dry and abandoned in Marshall, Love, Carter, Jefferson, Stephens, Caddo, Coal, Garvin and Roger Mills County. The Indian Territory Illuminating Oil Company's test south of Frederick, in Tillman County, created much excitement as a prospective pool opener, but water intrusion soon dispelled hopes. Wildcatting is expected to be concentrated in the southern and southwestern parts of the state in 1937. With deep tests seeking Ordovician pays, other wildcat tests will be drilled in southeastern Oklahoma, along the Nemaha trend in northern Oklahoma, and the northwestern part of the state. At the end of the year, the Carter Oil Co. was drilling a well in the north end of the Erick gas field and had a show of oil, which was thought to be coming from the Granite wash. Previously, the Erick field had produced only gas.

Water-flooding.—The activity in water-flooding as a means of secondary recovery in the older oil fields increased in 1936. Forest Oil Co. completed its operations on 160 acres in the old Nowata pool, and during a short period recovered oil from the 160-acre flooded tract at the rate of 3200 bbl. per day. At the end of the year, a large number of water-flood projects were under way in Nowata, Rogers, Osage, and Tulsa Counties. The engineers in the industry are solving many of the accompanying technical problems, and it appears that 1937 will see many more secondary recovery projects under way.

Gas Repressuring.—One of the outstanding secondary recovery projects was commenced during the year 1936 in the North Avant area. The Sinclair Prairie Oil Co., Phillips Petroleum Co. and Wolverine Petroleum Co. unitized a block of about 5000 acres, comprising more than 300 wells. Each of the companies assigned interest in the block which they owned in entirety to the other interested parties, so that the interests of each in the entire block were as follows: Phillips Petroleum Co., 41 per cent; Wolverine Petroleum Co., 29; Sinclair Prairie Oil Co., 30.

This operation was given approval by the Osage Indian Agency, and in order to encourage secondary recovery methods by this group the Osage Tribe reduced the royalty rate for a short period. The royalty interest under this unitized project presents no difficulty, as the Osage Tribe owns the oil royalty under the entire tract.

This is probably the first major secondary recovery project in which there has been a complete unitization of operating interests and royalty interests.

Many other gas repressuring projects are being carried on in northeastern Oklahoma, particularly in Osage County.

South Burbank Unitization Plan.—The unitization of the South Burbank field was an interesting development in the year 1935. The unit block comprised about 2400 acres and includes practically all of the producing acreage, save one or two leases. The producing formation is

being repressured with the gas that is produced along with the oil. Bottom-hole pressures have declined but little during the current year.

General.—The disposal of salt water is rapidly becoming one of the oil industry's principal waste problems. It has been reported that bills will be introduced in Congress bearing upon the disposal of waste from oil fields. At the 74th Congress, the Lonergan bill was introduced and hearings were held on it in February, 1936. The oil industry is going to be called upon shortly to face this problem and to determine what is to be done with the salt water that is produced with the oil. The U. S. Bureau of Mines has made one report on the Ritz-Canton oil field, in McPherson County, Kansas. It was found that more than 16,000 bbl. of salt water was being produced per day with the oil from this field. In the Fitts pool, E. H. Moore Co. has drilled a well across the Stonewall fault in the northwest corner of sec. 8, T. 2 N., R. 7 E. It was intended to use this well for a salt-water disposal well, by pumping the water from the Fitts pool to this point.

ACKNOWLEDGMENTS

The authors desire to acknowledge the assistance of Mr. W. J. Armstrong, of the Corporation Commission of the State of Oklahoma, and the records and data made available through his courtesy. The authors also acknowledge gratefully the assistance received from the following contributors: Lee A. Adams, Sinclair-Prairie Oil Co.; C. W. Tomlinson; Don R. Gearheart, Sinclair-Prairie Oil Co.; L. F. McCollum, Carter Oil Co.; C. H. Pishney, Amerada Petroleum Corporation; Merritt H. Brown, Darby Petroleum Corporation; R. W. Byars, Phillips Petroleum Co.; G. H. Beaulieu, Osage Indian Agency; C. G. Carlson; Dwight Thornton, Shell Petroleum Corporation; R. B. Roark, Shell Petroleum Corporation; E. N. Kemler, Gulf Oil Corporation; J. D. Wheeler, Ohio Oil Co.; and L. L. Foley.

Gas and Oil Development in Northwestern and Middle Pennsylvania during 1936

By J. G. MONTGOMERY, JR.*

AN increased drilling activity was apparent in the shallow sand fields of northwestern Pennsylvania during the year. This drilling, however, was confined to previously outlined productive areas and as new shallow sand pools of interest were discovered.

Drilling for Oriskany gas proceeded at about the same rate as in previous years. One new area in Kinzua township, Warren County, was opened up during the year by a producing well, but later this well developed salt water and the productive capacities of the area are very indefinite at the present time.

Production from the shallow sand areas remained approximately the same as in 1935. Production from the Oriskany or deep sand areas increased approximately 20 per cent.

Two new markets were made available for the Oriskany gas during the closing months of the year by the completion of the Peoples Natural Gas Co. line from the Hebron field to Clarion County, Pa. and Penn York Gas Co. line from the Harrison field to points in northwestern New York State.

With the exception of the Kinzua well, the few deep wildcat wells drilled during the year failed to discover new fields in the deep sands.

BRADFORD OIL FIELD

The accompanying data on the Bradford oil field include only the production obtained from the portion of that field that is in the State of Pennsylvania, for it appears probable that Cattaraugus County production, which consists mainly of the New York State portion of the Bradford field, will be included in annual oil production figures for New York State. The Bradford field production for 1936 totaled 14,533,000 bbl., and as it is necessary to estimate New York State production for the Bradford field, the accompanying data includes the production from the Pennsylvania end of the Bradford field of 13,208,000 bbl., which is an increase of approximately 8 per cent over 1935 production.

Manuscript received at the office of the Institute March 5, 1937.

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Estimates of well completions included the entire area, or both the New York and Pennsylvania portions of the Bradford field. Insufficient data were available to permit an accurate segregation of well completions.

Only two changes in crude prices occurred during the year, marking 1936 as a period of extremely stable prices. The price of crude varied from a low of \$2.30 to a maximum of \$2.57, and for the 350-day period, Jan. 13 to Dec. 28, the price was stabilized at \$2.45, with a weighted average for the entire year of \$2.446.

Changes in operating procedure and technique included gradual improvements rather than any completely new discoveries. The most important development in procedure consisted in the installation of chlorinating and other chemical treatment of the water used for flooding.

TABLE 1.—*Oil and Gas Production in Northwestern and Middle Pennsylvania*

Line Number	Field, County	Age, Years to End of 1936	Area Proved, Acres				Total Oil Production, Bbl. ³
			Oil ¹	Oil and Gas ²	Gas	Total	To End of 1936 ²
NORTHWESTERN PENNSYLVANIA							
1	Farmington, <i>Tioga</i>	7	0	0	y	y	329,476,xxx
2	Sabinsville, <i>Tioga</i>	2	0	0	y	y	
3	Hebron, <i>Potter</i>	4	0	0	y	y	
4	Ellisburg, <i>Potter</i>	3	0	0	y	y	
5	Harrison, <i>Potter</i>	2	0	0	y	y	
6	Clarion.....	y					
7	Clearfield.....	y					
8	Elk.....	y					
9	Forest.....	y					
10	Jefferson.....	y					
11	McKean.....	62	75,258	x	x	x	
12	Venango.....	y					
13	Warren.....	y					
MIDDLE PENNSYLVANIA							
14	Butler.....	23 to 68	66,000				
15	Clarion.....	48 to 67	20,000				
16	Crawford.....	14 to 77	6,000				
17	Elk.....	11 to 53	12,400				
18	Forest.....	52 to 72	22,000				
19	Lawrence.....	26 to 56	15,000				
20	Venango.....	49 to 77	84,000				
21	Sv. Warren.....	77	20,000				
22	Clarendon, Warren.....	15 to 77	29,000				
23	Total.....		274,xxx				

^a Footnotes to column headings and explanation of symbols are given on page 291.

¹ Acreage taken largely from compilation of Pennsylvania Geological Survey and revised by private estimates.

² Figures of oil production for individual districts or counties are not available and any estimate made of the total production for any district might be so inaccurate as to be misleading to anyone interested.

³ Acknowledgment is made to the Oil City Derrick for the figures on production and well completions.

MID-PENNSYLVANIA

The activity begun in 1935 continued through 1936 and with an increased rate in some localities. More producing and pressure wells were drilled than for several years previous, and these, together with the results of development in 1935, accounted for a total production of 2,939,200 bbl. in 1936, compared with 2,690,950 bbl. in 1935. In spite of the increased production in this section as well as in the Bradford field, stocks of crude decreased during the year and the new year begins with a healthy statistical position.

The price of crude, which is the controlling factor in this area, remained stable during the year at \$2.42. An increase of 15¢ to \$2.57 on Dec. 28, will add encouragement to the activity of 1937.

The oil development in the Middle district was a continuation of the work started in 1935. A sizeable amount of acreage was drilled on a

TABLE 1.—(Continued)

Line Number	Total Oil Production, Bbl. ³			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells								
	During 1935 ⁴	During 1936	Daily Average during Nov. 1936	To End of 1936	During 1935	During 1936	Maximum Daily during 1936	Completed to End of 1936	During 1936		At End of 1936					
									Completed	Abandoned	Temporarily Shut Down	Producing Oil Only ⁵	Producing Oil and Gas ⁶	Producing Gas Only	Total Producing	
1				32,939	4,606	3,419	x	y	y				0	0	y	y
2				4,224	115	4,109	x	12	9				0	0	12	12
3				39,334	14,627	4,548	x	32					0	0	32	32
4				36,418	12,070	23,900	x	33	9				0	0	33	33
5				1,754	3	1,751	x	7	5				0	0	7	7
6				x		1,979	x	x	71	y			x	x	x	x
7				x		51	x	x	2	y			x	x	x	x
8				x		3,200	x	x	4	y			x	x	x	x
9				x		222	x	x		y			x	x	x	x
10				x		4,046	x	x	27	y			x	x	x	x
11	12,193,332	13,208,855	36,800	x		1,408	x	x	3,207	y			36,xxx	x	x	x
12				x		2,800	x	x	27	y			x	x	x	x
13				x		1,120	x	x	2	y			x	x	x	x
14	2,690,950	2,939,200	8,030					x	4x	y	y		5,xxx			
15							x	9y	y	y	2,4xx					
16							x	4y	y	y	1,4xx					
17							x			y	1,2xx					
18							x	3y	y	y	1,6xx					
19							x	2y	y	y	6xx					
20							x	2yy	y	y	24,xxx					
21							x	1yy	y	y	8,xxx					
22							x	8y	y	y						
23																

⁴ Figures for counties are not available. Total production for the district known as Mid-Pennsylvania, or Kane to Butler, as reported by the *Oil City Derrick*.

⁵ Estimated, using as a basis a report of the Pennsylvania Statistical Department for 1934.

TABLE 1.—(Continued)

Line Number	Character of Gas, Approx. Average during 1936		Producing Rock							Deepest Zone Tested to End of 1936	
	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.	Name	Age ¹	Character ²	Porosity ³	Net Thickness, Average in Feet	Structure ⁴	Number of Dry and/ or Near-dry Holes to End of 1936	Name	Depth of Hole, Ft.
1	y	y	Oriskany	Dev	S	Por	30	AF	y	Oriskany	
2	y	y	Oriskany	Dev	S	Por	25	AF	y	Oriskany	
3	y	y	Oriskany	Dev	S	Por	15	AF	y	Oriskany	
4	y	y	Oriskany	Dev	S	Por	15	AF	y	Oriskany	
5	y	y	Oriskany	Dev	S	Por	15	AF	y	Oriskany	
6	y	y		Miss-Dev	S	Por	x	x	x		
7	y	y		Miss-Dev	S	Por	x	x	x		
8	y	y		Miss-Dev	S	Por	x	x	x		
9	y	y		Miss-Dev	S	Por	x	x	x		
10	y	y		Miss-Dev	S	Por	x	x	x		
11	y	y	Bradford	Dev	S	14.5	40	A	x	Medina	5,820
12	y	y		Miss-Dev	S	Por	x	x	x		
13											
14			Venango group	L Miss,	Ss	12	25	AMC	x	Oriskany	4,857
15			Venango group	U Dev	Ss	15	35				
16			and Lower	L Miss,	Ss	± 13	14	AMC	x y	y	
17			Venango 1st &	Dev	Ss,	10	15	AMC	x	Queenston shale	4,619
18			3rd	U Dev	Cong	25	40				
19			Kane	U Dev	Ss	12	38	AMC	x	Queenston shale	7,930
20			Venango group	U Dev	Ss,	10	20	AMC	x	Salina	5,252
21			and Lower		Cong	25					
22			Berea	L Miss	Ss	15	12	AMC	x	Helderberg ?	4,767
23			Venango group	U Dev	Ss,	10	10	AMC	x	Queenston shale	4,619
					Cong	25	40				
			Venango group	U Dev	Ss	10	10	AMC	x	Medina	5,288
						23	40				
			Clarendon Glade	U Dev	Ss	10	20	AMC	x	Oriskany	4,689
						25					

TABLE 2.—Summary of Drilling Operations in Northwestern Pennsylvania

Important Wildcats Drilled in 1936							
County	Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Initial Production per Day	Pressure, Lb. per Sq. In.	Remarks
					Gas, Millions Cu. Ft.	Casing	
1 Warren....	4688	Pottsville	Oriskany	H. & C. Drilling Co.	2	1740	Later Developed S.W.
2 Tioga.....	3690	Chemung	Oriskany	Penn United			Dry Hole
3 Potter.....	6280	Pocono	Oriskany	Godfry Cabot			Dry Hole
4 Potter.....	5376	Catskill	Oriskany	Godfry Cabot			Dry Hole
5 Crawford..	4465	Pocono	White Medina	Carnegie Gas Co.			Dry Hole

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1936.....		3
Number of oil wells completed during 1936.....		0
Number of gas wells completed during 1936.....		1
Number of dry holes completed during 1936.....		4

in unexplored territory failed in their purpose of bringing in any new pools or deeper oil pays.

ACKNOWLEDGMENTS

Acknowledgment is made to Mr. Norman E. Maxwell, of the Crew Levick Co., Titusville, Pa., for his data on the Mid-Pennsylvania field, and to Mr. Arthur C. Simmons, geologist and petroleum engineer of Bradford, Pa., for his data on the Bradford field.

Oil and Gas Developments in Tennessee in 1936

BY KENDALL E. BORN,* JUNIOR MEMBER A.I.M.E.

(New York Meeting, February, 1937)

PRODUCTION of crude oil in Tennessee during 1936 approximated 20,000 bbl., about the same as in 1935. Accurate figures are available only for the Glenmary field in southwestern Scott County and the Boone Camp, Seabolt, and Coon Hollow pools in north central Morgan County. Small amounts of oil were produced in the Poplar Cove region of eastern Fentress County, in Tinsleys Bottom along the line between Clay and Jackson Counties, and in the Lock Branch pool of northern Jackson County. The renewed interest in these three pools, which were abandoned for several years, reflects the effect of rising prices for crude oil in Tennessee. Developments in these fields were begun late in 1936 and therefore have had little effect on the production for the year. A number of small scattered wells in abandoned fields in Clay County were pumped intermittently during the year, but no production figures are available on this production.

The acidizing of a number of wells in Scott and Morgan counties reported last¹ year has been responsible for an increase of nearly 4000 bbl. over 1935 in this region. Results have shown, however, that the Glenmary pay (Glenmary and Coon Hollow pools) at about the top of the St. Louis limestone, responds more favorably to acid treatment than does the Boone Camp (Boone Camp and Seabolt pools) horizon in the Fort Payne formation of lower Mississippian age. This difference is probably due to the siliceous and argillaceous content of the Boone Camp pay.

The only natural gas marketed off the lease in Tennessee during 1936 was in Morgan County, where approximately 10,000,000 cu. ft. were furnished the towns of Sunbright and Burrville and the immediate vicinity. The gas occurs with the oil in the Boone Camp field and small amounts were put on the line from the near-by Coon Hollow and Seabolt pools. There are 11 gas wells in the area.

DEVELOPMENT

Although the presence of petroleum in Tennessee was noted more than one hundred years ago, this state has never been an important

Published with the permission of the State Geologist. Manuscript received at the office of the Institute Feb. 13, 1937.

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¹ W. F. Pond and K. E. Born: *Trans. A.I.M.E.* (1936) **118**, 350.

producer. Since the development of the first commercial oil pool on Spring Creek, in southern Overton County, in 1866, where 2600 bbl. of oil was pumped from the lower Mississippian at a depth of less than 30 ft., the history of oil and gas development in Tennessee has been essentially a story of sporadic drilling with the development of small, short-lived, shallow pools. The small initial capital required for shallow testing has resulted in numerous wildcat drilling operations with little accurate field work to justify the drilling. Naturally this has been reflected in an unusually high percentage of dry and near-dry holes. The deepest production in the state is less than 1500 ft. and little is known of the possibilities of deeper horizons. This is especially true of the Cum-

TABLE 1.—*Oil Production in Tennessee for 1936*

Line No.	Field, County	Age, Years to End of 1936	Production in 1936, Bbl.	Number of Wells Pumped in 1936	Producing Rock				Structure ¹
					Name	Age ^f	Character ^g	Porosity ^h	
1	Glenmary, Scott.....	20	5012	4	Glenmary	MisU	L	Fis	AF
2	Boone Camp, Morgan.....	12	1541½	12	Boone Camp	MisL	LS	Fis	T
3	Seabolt, Morgan.....	8	2250	4	Boone Camp	MisL	LS	Fis	T
4	Coon Hollow, Morgan.....	7	7532	3	Glenmary	MisU	L	Fis	T
5	Poplar Cove, Fentress.....	6	5xx	3	Sunnybrook	Ord	L	Fis	N
6	Tinsleys Bottom, Clay-Jackson.....	12	5xx	8	Tinsleys Bottom	Ord	L	Fis	A
7	Lock Branch, Jackson.....	9	5xx	8	Tinsleys Bottom	Ord	L	Fis	A

¹ Footnotes to column heads and explanation of symbols are given on page 291.

TABLE 2.—*Important Wildcat Tests Drilled in Tennessee during 1936*

Well Name	County	Location	Drilled by	Total Depth, Ft.	Surface Formation	Deepest Formation Tested	Remarks
Cobb Heirs.....	Fentress	4 miles south-west of Jamestown	S. P. Lollar et al.	Drilling	Warsaw		Produced some oil at 407 to 410 ft. Being drilled deeper.
Betty Coates.....	Sumner	3 miles west of Turners Station	George Schwab et al.	Drilling	Osage		Strong oil show in Silurian (Louisville) at 160 ft. Being drilled deeper.
Hub Perdue.....	Sumner	6½ miles north of Gallatin	Tennessee Fuel Gas Syndicate	1125	Middle Ord.	Jefferson City	Dry "St. Peter" test. Gas shows in "lower Sunnybrook" (Trenton).
V. P. Sampson.....	Smith	5 miles west of Carthage	T. G. Samson	1300	Lebanon	Upper "Knox"	Dry "St. Peter" test.
Jim Higgins.....	Cannon	7 miles north of Woodbury	E. M. Ellis et al.	1406	Cannon	Jefferson City	Dry "St. Peter" test. Gas and oil shows in Trenton and Stones River limestones.
M. Cooper.....	Fentress	8 miles south-west of Jamestown	Brandon Development Company	Drilling	Ste. Genevieve		Gas flow in Mississippian at 366 ft.
I. G. Wilson.....	Benton	6 miles north of Camden	S. H. Massey et al.	700	Camden	Beech River	Dry. Tested Devonian and Silurian possibilities in the Western Valley region.
J. A. Montgomery..	Decatur	4 miles west of Bath Springs	Clyde Washburn et al.	Drilling	Decatur?		Strong shows of oil and gas at about 1900 ft.
H. Jarrett.....	Haywood	1½ miles south of Brownsville	Henderson Oil Co.	4202	Grenada	Ordovician?	Dry. Reported gas shows in Cretaceous and Paleozoic.
F. B. Carroll.....	Obion	½ mile east of Minnick	Henderson Oil Co.	3418	Loess	Atoka?	Reported gas shows and some shale oil in the Atoka.

berland Plateau region, where relatively few wells have tested possibilities below the Chattanooga shale.

Twenty-three oil and gas tests were spudded in during 1936, nine of which are still drilling or only temporarily shut down. Of these wells, eight were drilled in the northeastern part of the Highland Rim; two in the eastern Highland Rim region; one on the northern Highland Rim; five in the Central or Nashville Basin; two in the Western Valley of Tennessee River; and five in the Mississippi embayment region of western Tennessee. There was only one producer and this well is now being drilled deeper. Three of the tests encountered considerable gas, but they have not been gauged to determine their commercial possibilities. The more important wildcat tests drilled in 1936 are given in Table 2.

CUMBERLAND PLATEAU

Although no wells were drilled in the Pennsylvanian area of the state during 1936, indications point toward a rather active drilling program in the northern part of the plateau for 1937. The gradual decline of production in the Glenmary pool in Scott County and the Boone Camp, Seabolt and Coon Hollow pools in Morgan County makes it necessary to seek increased production in this area. One well has been spudded in and an active drilling program has been outlined for the current year by the Russell Producing Co., which controls all production in Scott and Morgan Counties.

At present there is renewed interest in the possibilities of natural gas in the vicinity of Sunbright, in Morgan County, where several wells have encountered what are believed to be commercial reservoirs of gas within the middle and lower Mississippian. Although no detailed lithologic study has been made of these gas-bearing horizons, the accumulation appears to be largely governed by porous and fissured zones in the Mississippian limestones, with structure of secondary importance. A franchise has been obtained recently to distribute natural gas from this field in Knoxville, but further developments are pending an opinion by the Railroad and Public Utilities Commission. Provided permission is granted by the Commission, the Sunbright area of Morgan County will be subjected to an intensive drilling campaign during 1937.

NORTHEASTERN HIGHLAND RIM

The rise of crude-oil prices has focused interest on the possibilities of reworking some of the small shallow pools in eastern Clay, northern Jackson and eastern Fentress Counties, which in the past have produced considerable oil from Ordovician limestones.

Poplar Cove.—During the development of the Spurrier-Riverton pool in Pickett and Fentress Counties about 40 years ago, an attempt was

made to extend production to the east, and a small oil pool was found along Poplar Cove Creek 5 miles east of Riverton. Oil was produced there for a time but this pool declined along with the Spurrier-Riverton district after the removal of pipe lines in 1906. The production was from fissured and fractured Ordovician limestones 100 to 200 ft. below the Chattanooga shale.

In 1930 a new well in this old pool found a 1-ft. pay at 361.5 ft., 105.5 ft. below the top of the Chattanooga shale. Late in 1936 an old well near by, drilled a number of years ago, was put on pump and produced oil of about 25° Bé. An offset well was started and produced oil and water from the same horizon at 407 to 410 ft., 174 ft. below the top of the Chattanooga shale. This well is being drilled deeper and present plans include further drilling activities in this area during 1937.

Tinsleys Bottom.—A revival of the Tinsleys Bottom pool was begun late in 1936, and the development thus far has consisted in cleaning and pumping a number of old wells, several of which have responded to this treatment. A new test is drilling and any favorable shows will be acidized. If promising results are obtained, a number of the old wells will be treated with acid. A deep test is planned during the year.

The Tinsleys Bottom pool, developed in 1924, is along the boundary line of Clay and Jackson Counties between Gainesboro and Celina. The Leipers formation, of upper Ordovician age, forms the surface rock in the immediate area and is overlain unconformably in the surrounding hills by the Chattanooga black shale. Geologic work has shown that a well defined anticlinal fold, along with local porosity conditions in the lower Ordovician limestones, accounts for the accumulation. The principal production has been obtained between 50 and 150 ft. below the "Pencil Cave" (a bentonitic clay horizon near the top of the Lowville) or 550 to 650 ft. below the Chattanooga shale. This producing horizon is correlated with the Lowville (Black River) and Lebanon (Stones River) limestones. The oil has a paraffin base and is of high quality, ranging from 38° to 45° Bé. Some 25 wells have been drilled in the field but less than one-half of the area of favorable structure has been tested.

Lock Branch.—The Lock Branch pool is in the north-central part of Jackson County, 6 miles north of Gainesboro and a few miles south of the Tinsleys Bottom field. The discovery well was completed in April 1927 at a depth of 283 ft., 71 ft. below the Pencil Cave and 583 ft. below the base of the Chattanooga black shale. The flush production was reported at 200 bbl. and the producing horizon appears to be the upper part of the Stones River group, approximately the equivalent of the Tinsleys Bottom pay. About 14 producing wells have been reported in this pool, but there has been little production and it has been difficult for this Division to obtain reliable data on the developments. Plane-table work on the Chattanooga shale in the surrounding hills indicates a well defined dome.

There has been small production in the Lock Branch pool during 1936 and reports indicate further developments in this area for the current year.

Clay County.—The drilling in of a flowing well reported at 100 bbl. per day in December 1936, along the Kentucky-Tennessee line just north of Lillydale, will undoubtedly revive interest in eastern Clay County. This well was an old well deepened to 726 ft. from 711 ft., where there was small production in 1927. The producing horizon is below the Pencil Cave and probably about the equivalent of the Tinsleys Bottom pay. Blocks of acreage have been taken up in the northeastern part of Clay County and adjacent Kentucky and two wells have already been spudded in.

The Peterman Bend field, after being temporarily abandoned for several years, is leased again, with plans to pump the old wells and drill some deeper tests. This field, discovered in 1925, is just east of Celina along Obey River in central Clay County. Several thousand barrels of oil have been produced from about a dozen wells just below the Pencil Cave, and deeper drilling found production in the Tinsleys Bottom pay. The depth of the wells ranges from 300 to 500 ft. and Pencil Cave elevations indicate that the production is the result of anticlinal accumulation.

During 1936 the Fox Springs oil pool in eastern Clay County, between Celina and Willow Grove, was permanently abandoned and all equipment removed. This field was developed in 1927 and considerable oil was produced from depths of about 200 feet.

MIDDLE TENNESSEE

There were only two wells drilled on the eastern Highland Rim during 1936. Gas shows were reported below the Chattanooga shale in the "Sunnybrook" horizons of middle Ordovician age, and although both tests were drilled below the Pencil Cave, no favorable shows were encountered in rocks that produce to the north in Clay and Jackson Counties.

Several blocks of acreage were taken during the year on the northern Highland Rim, due largely to increased activity in the adjoining counties of Allen and Monroe in Kentucky. In Tennessee only one well was drilled during 1936. This test, in northern Sumner County, penetrated the Chattanooga shale at 100 to 135 ft. and found a strong show of oil in the Silurian (Louisville) limestone at 160 ft. This test is being drilled deeper.

Although small amounts of oil have been produced in northern Sumner County from the Silurian, attempts to extend the Allen County, Kentucky, production to the south have not been successful. It appears that the "Corniferous," which is productive in Allen County, thins out near the state line and the Silurian thus far has not proved of commercial importance in Tennessee, probably due to porosity conditions. Relatively few wells on the northern Highland Rim west of the Cincinnati

axis have been carried deeper than 100 ft. below the black shale, consequently little is known of the Trenton and lower Ordovician possibilities.

Five wells were drilled during the year in the Nashville Basin, three of which were carried for varying distances into the Knox dolomite. No shows were reported in the St. Peter horizon immediately above the Knox. Two of these tests, in Cannon and Smith Counties, encountered strong flows of mineralized water in the Jefferson City formation (upper Knox). An insoluble residue study from the third well, drilled about 35 miles north of Nashville, in Sumner County, showed a few well rounded and frosted sand grains of the St. Peter type at 956 ft., but no oil shows were noted.

In the Western Valley of the Tennessee River a well in southern Decatur County reported a strong flow of gas and oil show at 1900 ft., about 1000 ft. below the top of the Knox dolomite. Unfortunately, this well was drilled with considerable water in the hole. This test is on the old Dunbar structure and is the second well drilled deeper than 1800 ft. on this anticline. A well north of Camden in the Western Valley started in the Camden chert and tested Devonian and Silurian possibilities to a depth of 700 ft. without finding encouraging shows.

Interest persists in the Mississippi embayment area in Tennessee, where five wells were started or completed during the year. Since most of these tests were on surface structures or without regard to structural conditions, they must be considered rank wildcat ventures. It is to be regretted that geophysical work did not precede this testing. This Division has repeatedly emphasized the unreliability of surface indications in the determination of subsurface conditions in a region of essentially unconsolidated sands, clays and gravels, such as form the surface of western Tennessee. Very little geophysical exploration has been carried on in the Mississippi embayment region of Tennessee, but it is believed that such work would indicate the presence of structures that are not reflected in the surface Coastal Plain sediments. Because of the probable strong faulting in the underlying Paleozoic floor, the Reelfoot Lake region probably would be especially reactive to geophysical prospecting.

The Henderson Oil Company's No. 2 well in central Haywood County was drilled to a reported depth of 4202 ft., the deepest test in West Tennessee. The driller's log reported Chattanooga black shale at 2880 to 2905 ft. and the well probably finished in the Ordovician.

The most interesting well drilled in Tennessee during the past year was a test in southwestern Obion County, drilled to 3418 ft. After a normal Coastal Plain section, this well encountered the top of the Paleozoic floor at about 2700 ft. A core specimen at 2773 ft. showed a strong dip, suggesting that the well had entered disturbed beds underlying the Reelfoot Lake region. Cuttings to 3295 ft. were dark gray to black micaceous shales with some very thin, gray limestone beds. Some of the

shale showed a pronounced slaty cleavage. These cuttings have been tentatively correlated with the Atoka formation of lower Pennsylvanian age, which outcrops over a large area in the Arkansas Valley region to the southwest. Provided the correlation of the Paleozoic rocks is correct, the presence of lower Pennsylvanian beds in the northern part of the Mississippi embayment complicates the generally accepted idea concerning the pre-Cretaceous development of this part of the embayment. Based upon available cuttings and well records, the Paleozoic floor in the southern and central parts of West Tennessee have been considered Mississippian in age, with older beds, probably Ordovician, forming the floor in the northern part of the embayment². Two wells now drilling in the Reelfoot Lake region will undoubtedly give additional data on this problem.

A well now drilling near Ridgely, in southern Lake County, logged the top of the Midway (Porters Creek clay) at 1490 ft., almost 300 ft. higher than the Midway top in the Bradshaw test just 5 miles to the southeast. Another test, at Hornbeak, in west central Obion County, is now drilling at approximately 1800 ft. This well is being cored at frequent intervals and it will probably be the first well drilled in the Mississippi embayment area in Tennessee to offer the opportunity for a detailed study of the embayment sediments.

The well mentioned last year³ to be drilled on a reported seismic high in Tipton County was lost above the Paleozoic floor.

ACKNOWLEDGMENTS

The writer acknowledges with thanks the cooperation of Mr. Ralph Mong, of the Russell Producing Co., who furnished data on Scott and Morgan Counties.

² K. E. Born: Notes on the Upper Cretaceous Tertiary Sub-Surface Stratigraphy of Western Tennessee. *Jnl. Tenn. Acad. Sci.* (1935) **10**, 262-263.

³ W. F. Pond and K. E. Born: *Trans. A.I.M.E.* (1936) **118**, 351.

Petroleum in the Central Texas Area during 1936

By W. C. BEDNAR,* JUNIOR MEMBER A.I.M.E.

IN all, 127 producing oil wells, 8 producing gas wells and 212 dry holes were drilled during 1936 in the Central Texas area; 76 wells in Bexar County, 62 in Caldwell County, 44 in Guadalupe County, 22 in Williamson County, 20 in Navarro County and 20 in Frio County. Less than 20 were drilled in each of the other counties and none at all in Ellis, Hill, Bosque, Coryell, Lampasas, Burnet, Llano, Kennedy, Mason, Real, Kinney and Uvalde Counties.

The Pearsall-Austin chalk field in Frio County and the Zoboroski field in Guadalupe County were the only new discoveries and there were no important extensions to old fields.

In this report Corsicana, Mildred (Elm Ridge), Angus-Edens-Hodge, Burke, and Rice-Oil Ridge, all shallow Navarro County stripper fields, are grouped together under the name of Corsicana. This grouping follows that of the Railroad Commission of Texas, thus facilitating the gathering of production data.

A map showing the location of the oil and gas fields in the Central Texas Area was published in Volume 114 of the A.I.M.E. TRANSACTIONS, page 380.

NEW FIELDS

Pearsall-Austin Chalk.—The Amerada Petroleum Corporation completed 13 Austin chalk wells during 1936 on the large Amerada-Rycade block in Frio County. Other companies drilled two dry holes to the Austin chalk in this vicinity. Not enough wells were drilled to give control of the structure but it appears to be a nose plunging in a west-southwest direction. A second deep test is being drilled in the Pearsall area and at this writing has cemented off a show of oil and gas in the Edwards limestone.

The Humble Oil and Refining Co. is building a 6-in. pipe line from Lytle, Tex., to serve the Pearsall field.

Zoboroski.—Actual discovery of the Zoboroski field was made by W. J. Walton et al. in 1931. The discovery well, Anton Zoboroski No. 1, was a small producer making but from 3 to 5 bbl. per day, which was used locally for fuel oil. The discovery of the Darst Creek Extension in

Manuscript received at the office of the Institute March 11, 1937.

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TABLE 1.—Oil and Gas Production in the Central Texas Area

Line Number	Field, County	Age, Years to End of 1936	Area Proved, Acres		
			Oil	Gas	Total
1	Corsicana ¹ , Navarro.....	40	6,710	0	(2,610) 6,710
2	Mildred (Elm Ridge) ² , Navarro.....	36			
3	South Bosque, McLennan.....	34	2,500	0	2,500
4	Somerset, Atascosa, Bexar.....	24	11,390	0	11,390
5	Gas Ridge, Bexar.....	24	150	300	450
6	Thrall, Williamson.....	22	475	0	475 (500)
7	Angus-Edens-Hodge ³ , Navarro.....	21			
8	Burke ² , Navarro.....	21			
9	Alta Vista, Bexar.....	21	300	0	300
10	Rice-Oil Ridge ² , Navarro.....	20			
11	Mexia, Limestone.....	16	3,920	0	3,920
12	Minerva-Rockdale, Milam.....	15	4,000	0	4,000
13	Luling, Caldwell, Guadalupe.....	15	2,130	0	2,130
14	Yturri-Southton, Bexar.....	15	500	0	500 (10)
15	Chilton, Falls.....	14	40	0	40
16	Currie, Navarro.....	14	475	0	(150) 475
17	Ina, Medina.....	14	310	0	310
18	Powell, Navarro.....	13	2,600	0	2,600 (450)
19	Adams, Medina.....	12	0	2,000	(60) 2,000
20	Richland, Navarro.....	12	440	0	440
21	Woodbine Area (Shallow-Powell), Navarro.....	12	750	0	750
22	Bains Creek, Limestone.....	12	0	60	60
23	Taylor, Medina.....	12	30	0	30
24	Lytton Springs, Caldwell.....	11	1,360	0	1,360 (70)
25	Wortham, Freestone Limestone.....	11	715	0	715
26	Chittam, Maverick.....	10	0	320	320
27	Dale, Caldwell.....	9	190	0	190
28	Eckert, Bexar.....	9	640	80	720
29	Salt Flat, Caldwell.....	9	1,195	0	1,195
30	Larremore, Caldwell.....	9	50	0	50
31	Yost, Bastrop.....	8	97	0	97
32	Cow Hill, Zavalla.....	8	0	1,000	1,000
33	Darst Creek, Guadalupe.....	8	1,670	0	1,670
34	Buchanan, Caldwell.....	8	75	0	75
35	Chapman, Williamson.....	7	560	0	560
36	Manford, Guadalupe.....	7	30	0	30
37	Dunlap, Caldwell.....	6	70	0	70
38	Branyon ⁴ , Caldwell.....	6	230	0	230
39	Chicon Lake, Medina.....	6	350	75	425
40	Carroll, Bastrop.....	4	40	0	40
41	North Dale, Bastrop.....	4	250	0	250
42	Hilbig, Bastrop.....	4	250	0	250
43	Cedar Creek, Bastrop.....	4	160	0	160
44	Byersville, Williamson.....	3	360	0	360
45	Pearsall-Georgetown, Frio.....	3	0	160	160
46	Von Ormy, Bexar.....	3	540	0	540
47	Red Lake, Freestone.....	2½	0	2 ²²	2 ²²
48	Pearsall-Upper Sand, Frio.....	2	400 ²⁰	0	400

¹ Includes Mildred, Angus-Edens-Hodge, Burke, and Rice-Oil Ridge.² Included with Corsicana.³ Includes shallow production.²⁰ 100 acres per well. Limits not defined.²² Limits not defined.

TABLE 1.—(Continued)

Line Number	Total Oil Production, Bbl.				Total Gas Production, Millions of Cu. Ft.				Number of Oil and/or Gas Wells		
	To End of 1936	During 1935	During 1936	Daily Average during Nov. 1936	To End of 1936	During 1935	During 1936	Maximum Daily during 1936	Completed to End of 1936	During 1936	
										Completed	Abandoned
1	13,696,965	165,260	166,750	421	0	0	0		2,937	2	0
2											
3	88,830	3,480	4,380	12	0	0	0		123	0	0
4	9,892,585	267,385	254,315	765	0	0	0		1,052	4	14
5	60,679	2,589	1,030	7	1,108	131	114	0.5	120	0	1
6	2,389,497	16,920	18,615	41	0	0	0		16	1	0
7											
8											
9	104,199	1,820	1,719	5	0	0	0		41	0	0
10	94,689,502	801,586	765,798	1,999	0	0	0		550	0	5
11	3,256,561	79,442	78,792	197	0	0	0		575	0	0
12	65,284,132	2,013,097	2,093,993	5,938	0	0	0		599	0	0
13											
14	582,666	24,371	21,534	66	0	0	0		138	6	0
15	92,630	710	1,560	4	0	0	0		3	0	0
16	6,708,774	50,067	44,154	126	0	0	0		54	0	2
17	149,159	2,116	3,393	19	0	0	0		31	0	0
18	107,720,268	812,208	804,989	2,319	0	0	0		741	0	2
19	0	0	0		11,771	348	302	1.0	46	0	4
20	6,612,285	10,740	6,795	15	0	0	0		107	0	0
21	3,773,968 ^a	38,160 ^a	11,868	31	0	0	0		247	10	0
22	0		0		x ⁴	224	34	0.1	5	0	0
23	29,002	1,710	1,628	0	0	0	0		6	0	1
24	8,055,400	142,345	130,736	361	0	0	0		359	5	3
25	22,461,927	35,716	30,327	69	0	0	0		322	0	0
26	0	0	0		5,781.8	745	1,182	5	5	0	0
27	1,333,894	64,788	83,346	179	0	0	0		46	4	0
28	744,229	118,124	85,215	20	x ⁵	220	x ⁵	x	136	1	0
29	35,076,298	1,505,883	1,467,129	4,164	0	0	0		359	6	3
30	245,337	17,835	16,647	46	0	0	0		13	0	0
31	856,911	26,066	11,552	27	0	0	0		25	0	3
32	0	0	0		x ⁵	27.4	x ⁵	x	7	0	0
33	38,632,169	3,285,033	3,266,651	9,080	0	0	0		282	21	19
34	182,138	13,789	12,864	33	0	0	0		11	5	3
35	3,969,333	143,004	118,944	326	0	0	0		114	0	12
36	371,384	13,204	11,454	42	0	0	0		4	0	1
37	259,931	16,484	19,232	32	0	0	0		10	2	1
38	141,038	10,343	56,782	602	0	0	0		23	18	0
39	22,089	5,662	5,627	21	x ²⁴	50	x ²⁴	x	28	0	0
40	45,742	19,405	16,187	167	0	0	0		5	1	0
41	434,896	90,655	73,366	179	0	0	0		20	0	0
42	1,057,865	277,827	259,453	605	0	0	0		12	0	0
43	194,600	27,237	16,863	34	0	0	0		16	0	0
44	357,900	192,614	118,786	298	0	0	0		34	4	0
45	0	0	0		106	0	0	0	1	0	0
46	56,056	13,908	40,156	116	0	0	0		54	17	0
47	0	0	0		627	140	487	6	3	1	0
48	46,131	8,600	37,531	0	0	0	0		4	0	0

^a Production estimated.⁴ Production estimated.⁵ No gas records available.²⁴ No gas records available.²⁵ Shut in during all of 1936.

TABLE 1.—(Continued)

Line Number	Number of Oil and/or Gas Wells					Depth, Average in Feet		Oil Production Methods at End of 1936			Pressure, Lb. per Sq. In. ^d			Character of Oil, Approx Average during 1936					
	At End of 1936					Bot- toms of Pro- ductive Wells	To Top of Pro- ductive Zone	Number of Wells			Average at End of			Gravity A.P.I. at 60° F.					
	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas ^b	Producing Gas Only	Total Producing			Flowing	Pump- ing	Gas-lift	Initial	1935	1936	Maximum	Minimum	Weighted Average	Sulphur, Per Cent	Base ^c	
1	0	634	0	0	634	1,260	460	0	634	0	x	x	x	37.1	18.0	x	0.5	P	
2																			
3	0	30	0	0	30	475	450	0	30	0	x	x	x	42	40	41	0.2	P	
4	x	951	0	0	951	2,100	1,400	0	951	0	x	x	x	39.4	34.4	36.4	1.4	P	
5	0	12	0	66	78	830	780	0	12	0	x	x	x	23	21	22	0.4	P	
6	0	16	0	0	16	1,000	700	0	16	0	x	x	x	37.6	36.4	37	0.3	P	
7																			
8																			
9	0	12	0	0	12	250	220	0	12	0	x	x	x	36	34	35	0.3	P	
10																			
11	14	250	0	0	264	3,085	3,000	0	264	0	x	x	x	36	34	35	0.3	P	
12	0	443	0	0	443	1,700	600	0	443	0	x	x	x	40	36	38	0.2	P	
13	0	501	0	0	501	2,200	2,100	0	501	0	x	x	x	28	26	27	0.9	A	
14	0	104	0	0	104	800	600	0	104	0	x	x	x	33	31	32	0.5	P	
15	0	1	0	0	1	1,160	1,080	0	1	0	x	x	x	33	31	32	0.8	P	
16	0	13	0	0	13	2,990	2,930	0	13	0	x	x	x	40	40	40	0.2	P	
17	0	7	0	0	7	960	940	0	7	0	x	x	x	19	19	19	0.7	A	
18	7	120	0	0	127	3,000	2,925	0	127	0	x	x	x	38	36	37	0.3	P	
19	0	0	0	16	16	1,000	900	0	0	0	400	115	100	Gas only					
20	0	3	0	0	3	3,040	2,975	0	3	0	x	x	x	38	38	38	0.3	P	
21	0	38	0	0	38	1,650	850	0	38	0	x	x	x	34.8	23.5	33	0.4	P	
22	2	0	0	0	2	2,960	2,945	0	0	0	875	180	y	Gas only					
23	1	1	0	0	2	400	290	0	2	0	x	x	x	18	18	18	0.4	P	
24	10	162	0	0	172	1,900	1,600	0	172	0	x	x	x	39	37	38	0.4	P	
25	0	7	0	0	7	3,050	2,990	0	7	0	x	x	x	38.6	36.2	37.3	0.2	P	
26	0	0	0	3	3	5,590	5,525	0	0	0	2,200	1,210	1,100	Gas only					
27	0	41	0	0	41	2,250	1,915	0	41	0	x	x	x	38	36	37	0.2	P	
28	0	127	0	5	132	790	620	0	127	0	x	x	x	35	33	34	0.3	P	
29	0	219	0	0	219	2,740	2,670	0	219	0	x	x	x	36	36	36	0.6	P	
30	0	8	0	0	8	1,315	1,285	0	8	0	x	x	x	23	23	23	0.6	P	
31	0	5	0	0	5	1,500	1,335	0	5	0	x	x	x	28	26	27	0.3	P	
32	0	0	0	7	7	800	675	0	0	0	295	210		Gas only					
33	0	258	0	0	258	2,700	2,650	0	258	0	x	x	x	37	35	36	0.8	P	
34	0	7	0	0	7	2,075	1,750	0	7	0	x	x	x	37	35	36	0.2	P	
35	0	74	0	0	74	1,915	1,730	0	74	0	x	x	x	36.7	35.2	36	0.2	P	
36	0	1	0	0	1	2,320	2,260	0	1	0	x	x	x	37.3	36.7	37.3	0.9	P	
37	0	7	0	0	7	2,300	2,290	0	7	0	x	x	x	37	35	36	0.6	P	
38	2	21	0	0	23	2,000	1,900	0	23	0	x	x	x	38	36	37.5	0.8	P	
39	1	21	0	6	28	810	760	0	22	0	420	200	x	36	34	35	0.1	P	
40	5	5	0	0	5	2,378	2,300	0	5	0	x	x	x	36	36	36	0.2	P	
41	1	15	0	0	16	2,160	2,025	0	16	0	x	x	x	38	36	37	0.3	P	
42	0	12	0	0	12	2,575	2,450	11	0	1	1,240	1,035	x	37	37	37	0.2	P	
43	1	10	0	0	11	1,700	1,650	0	11	0	x	x	x	34	34	34	0.2	P	
44	4	30	0	0	34	900	850	0	34	0	x	x	x	37	37	37	0.2	P	
45	1	0	0	0	1	6,459	6,400	0	0	0	2,120	x	x	Gas only					
46	5	49	0	0	54	730	500	0	54	0	x	x	x	34	34	34	0.4	P	
47	0	0	0	3	3	4,950	4,850	0	0	0	1,855	1,855	1,855	Gas only					
48	4	0	0	0	4	3,935	3,920	4	0	0	x	x	x	26	26	26	0.1	M	

^b Footnotes to column heads and explanation of symbols are given on page 291.

TABLE 1.—(Continued)

Line Number	Character of Gas, Approx. Average during 1936		Producing Rock						Number of Dry and/ or Near-dry Holes to End of 1936	Deepest Zone Tested to End of 1936	
	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Name	Age ¹	Character ²	Porosity ⁴	Net Thickness, Average in Feet	Structure ⁵		Name	Depth of Hole, Ft.
1	1,040	1.8	Nacatoch, Corsicana, Na- varro-Taylor	CreU	Ss	12-20	15	A AF-AM	549	Woodbine	3,570
2											
3	1,225	2	Basal Walnut	CreL	DL	22	3	AF	100	Basal Trinity	1,800
4	x	x	Taylor-Navarro	CreU	SH	22	30	TF	75	Trinity sand	5,311
5	1,120	0.5	Taylor sand	CreU	SH	15-20	15	A	39	Glenrose	2,250
6											
7	x	0.8	Serpentine	CreU	P	20-30	x	Intn.	23	Trinity sand	3,290
8											
9	1,135	x	Navarro sand	CreU	S	15-20	23	F	28	Trinity sand	4,535
10											
11	1,152	2.5	Woodbine sand	CreU	SH	25	50	F	146	Trinity sand	6,044
12	x	2.5	Upper Navarro	CreU	S	16	15	F	46	Edwards	5,000
13	955	1.5	Edwards Limestone	CreL	L	5-30	100	F	83	Schist	7,859
14											
15	x	1.8	Navarro sand	CreU	S	16	10	F	36	Glenrose	3,850
16	x	2.1	Georgetown	CreL	LS	23	5	AF	23	Glenrose	2,025
17											
18	1,040	2.5	Woodbine sand	CreU	SH	22	20	F	53	Woodbine	3,646
19	x	x	Escondido sand	CreU	SH	x	15	F	34	Edwards	2,048
20											
21	1,080	2.5	Woodbine sand	CreU	SH	25	45	F	68	Trinity sand	6,506
22											
23	999	2.3	Escondido sand	CreU	S	x	20	F	12	Edwards	2,289
24	1,060	2.5	Woodbine sand	CreU	SH	25	20	F	23	Glenrose	5,415
25	x	x	Navarro-Taylor	CreU	Ss	14-20	15	AF	54	Trinity	6,506
26	1,040	0.4	Woodbine sand	CreU	SH	20	15	F	9	Woodbine sand	3,208
27											
28	x	1.4	Taylor sand	CreU	SH	15	15	Crev.	15	Edwards	1,285
29											
30	1,040	1.5	Serpentine	CreU	P	14	x	Intn.	47	Edwards	2,292
31	1,080	2.5	Woodbine sand	CreU	SH	25	35	F	63	Glenrose	4,825
32	1,120	4.6	Glenrose	CreL	L	x	50	A	8	Basal Trinity	7,635
33	x	1.5	Serpentine	CreU	P	15	x	Intn.	8	Edwards	2,661
34	1,140	1.8	Navarro	CreU	S	16	10	F	16	Edwards	1,590
35	x	2.5	Edwards	CreL	L	30	30	F	39	Edwards	2,918
36	1,120	1.3	Edwards	CreL	L	x	35	F	8	Glenrose	2,150
37	x	1.4	Serpentine	CreU	P	15-25	x	Intn.	8	Austin chalk	2,066
38	1,015	0.2	Escondido sand	CreU	SH	x	20	A	10	Glenrose	4,709
39	x	2.3	Taylor marl, Austin chalk, Edwards	CreL	L	26	30	F	28	Edwards	3,200
40											
41	x	1.6	Serpentine	CreU	P	12	x	Intn.	5	Edwards	2,483
42	1,025	0.8	Serpentine	CreU	P	20	x	Intn.	50	Edwards	3,226
43	x	1.5	Edwards	CreL	L	35	30	F	4	Edwards	2,800
44	x	1.5	Austin chalk	CreU	C	x	10	F	10	Edwards	2,420
45											
46	x	1.5	Crevice Top Austin, Navarro, Taylor	CreU	C-S	x	x	F	10	Edwards	2,450
47											
48	1,095	0.5	Serpentine	CreU	P	13	x	D	13	Edwards	1,725
49	1,025	2.5	Serpentine	CreU	P	12	x	Intn.	3	Edwards	2,919
50	x	1.5	Serpentine	CreU	P	15	x	Intn.	18	Edwards	2,950
51	1,300	1.0	Serpentine	CreU	P	12	x	Intn.	5	Serpentine	2,715
52	1,010	0.5	Serpentine	CreU	P	15-25	x	Intn.	5	Edwards	2,300
53	1,010	2.0	Serpentine	CreU	P	15-25	x	Intn.	20	Edwards	2,353
54											
55	x	x	Georgetown	CreL	L	x	59	N	0	Edwards	6,507
56	x	x	Midway, Taylor	CreU	SH	x	21	F	19	Edwards	2,835
57	1,040	x	Woodbine sand	CreU	S	x	25	x	1	Woodbine	5,002
58	x	x	Navarro sand	CreU	S	20	15	N	3	Trinity	10,050

1935 led to further development in the Zoboroski field and eight commercial oil wells were completed during 1936. The oil, found in crevices in the Austin chalk, is of paraffin base with a greenish color and has a gravity of 31.4° A.P.I.

EXPLORATION

Production was not found in any of the dry counties in the Central Texas area during the year 1936.

Three important wildcats were drilled in Zavalla County west of the Amerada-Rycade Frio County block. Two of these were abandoned in the Austin chalk and the third in the Edwards limestone.

A third Trinity sand test was made in the Mexia field and was abandoned at 6064 ft. after testing salt water with shows of oil and gas.

TABLE 1.—(Continued)

Line Number	Field, County	Age, Years to End of 1936	Area Proved, Acres		
			Oil	Gas	Total
49	Darst Creek Extension, <i>Guadalupe</i>	1½	760	0	760
50	Pearsall-Austin chalk, <i>Frio</i>	1	520 ²¹	0	520
51	Zoboroski, <i>Guadalupe</i>	1	65	0	65
DEPLETED FIELDS					
52	Chatfield ⁷ , <i>Navarro</i>	Life			
53	Mission ⁸ , <i>Bezar</i>	5 Yr.	0	150	150
54	Witherspoon-McKie ⁹ , <i>Navarro</i>	16 Yr.	200	0	200
55	Kosse ¹⁰ , <i>Limestone</i>	20 Yr.	400	0	400
56	Nigger Creek ¹¹ , <i>Limestone</i>	8 Da.	10	0	10
57	Cedar Creek ¹² , <i>Limestone</i>	5 Yr.	170	0	170
58	Ottine ¹³ , <i>Gonzales</i>	4 Yr.	30	0	30
59	Lytton Springs Townsite ¹⁴ , <i>Caldwell</i>	6 Mo.	10	0	10
60	Marlin-Satin ¹⁵ , <i>Falls</i>	6 Yr.	50	0	50
61	Cooksey ¹⁶ , <i>Bezar</i>	3 Yr.	10	0	10
62	Schimmel-Batts ¹⁷ , <i>Bastrop</i>	7 Yr.	50	0	50
63	Manda ¹⁸ , <i>Travis</i>	6 Yr.	50	0	50
64	Pearsall-Buda ¹⁹ , <i>Frio</i>	2 Yr.	40	0	40
		7 Mo.	40	0	40
65	Total.....		48,357	4,145	52,502

⁷ Discovered 1905; depleted 1910.

⁸ Discovered 1912; depleted 1928.

⁹ Discovered 1915; depleted 1935.

¹⁰ Discovered 1922; depleted 1922.

¹¹ Discovered 1926; depleted 1931.

¹² Discovered 1927; depleted 1931.

¹³ Discovered 1929; depleted 1929.

¹⁴ Discovered 1930; depleted 1935.

¹⁵ Discovered 1932; depleted 1935.

¹⁶ Discovered 1929; depleted 1936.

¹⁷ Discovered 1930; depleted 1936.

¹⁸ Discovered 1934; depleted 1936.

¹⁹ Discovered 1935; depleted 1936.

²¹ 40 acres per well. Limits not defined.

OIL RECOVERY

Favorable prices for crude oil during 1936 caused the abandonment of many stripper wells to be postponed. In the shallow fields of Navarro

County and in the Somerset field of Bexar and Atascosa Counties a large number of wells are being pumped for less than $\frac{1}{4}$ bbl. of oil per day each.

During 1936 the Central Texas area produced 10,629,616 bbl. of oil from 4243 wells, an increase of 269,261 bbl. over the production of the previous year. The daily average per well during 1936 was 6.9 bbl., as compared to 7.6 bbl. during 1935.

Table 3 shows the accumulated production from the Central Texas area subdivided into geologic zones.

PRORATION

The Pearsall-Austin chalk, Darst Creek Extension, and Zoboroski fields were the only fields in the Central Texas area with potentials large enough to necessitate proration by the Railroad Commission of Texas. The majority of wells in the Central Texas area do not produce more than the marginal well allowance.

All gas wells in the Central Texas area conformed to the rulings of the Railroad Commission relating to potential tests and conservative withdrawals.

TABLE 1.—(Continued)

Line Number	Total Oil Production, Bbl.				Total Gas Production, Millions of Cu. Ft.				Number of Oil and/or Gas Wells		
	To End of 1936	During 1935	During 1936	Daily Average during Nov. 1936	To End of 1936	During 1935	During 1936	Maximum Daily during 1936	Completed to End of 1936	During 1936	
										Completed	Abandoned
49	131,449	6,435	125,014	282	0	0	0		9	6	0
50	291,729	0	291,729	68	0	0	0		13	13	0
51	45,785 ²³	2 ²³	41,285	271	0	0	0		9	8	0
DEPLETED FIELDS											
52	0	0	0		4,750	0	0		15	0	0
53	63,000	0	0	0	0	0	0		32	0	0
54	810,495	0	0	0	0	0	0		85	0	0
55	33,000	0	0	0	0	0	0		1	0	0
56	2,998,810	0	0	0	0	0	0		75	0	0
57	297,945	0	0	0	0	0	0		14	0	0
58	12,000	0	0	0	0	0	0		1	0	0
59	6,273	10	0	0	0	0	0		3	0	0
60	1,560	440	0	0	0	0	0		2	0	0
61	67,228	6,137	1,686	0	0	0	0		15	0	15
62	4,301	624	77	0	0	0	0		6	0	6
63	15,736	10,627	4,696	0	0	0	0		2	0	2
64	20,867	15,899	4,968	0	0	0	0		1	0	1 ²⁶
65	434,476,148	10,360,355	10,629,616		24,143.8	1,683.4	2,088		9,567	135	98

²³ Estimated 4500 bbl. previous to commercial development.

²⁶ Plugged back to perforate Austin chalk.

TABLE 1.—(Continued)

Line Number	Number of Oil and/or Gas Wells					Depth, Average in Feet		Oil Production Methods at End of 1936			Pressure, Lb. per Sq. In. ^a		Character of Oil, Approx. Average during 1936					
	At End of 1936					Bot-toms of Pro-ductive Wells	To Top of Pro-ductive Zone	Number of Wells			Average at End of		Gravity A.P.I. at 60° F.					
								Flow-ing	Pump-ing	Gas-lift	Initial	1935	1936	Maximum	Minimum	Weighted Average	Sulphur, Per Cent	Base ^c
	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas ^b	Producing Gas Only	Total Producing													
49	0	9	0	0	9	2,450	2,375	0	9	0	x	x		34	34	34	0.5	P
50	3	10	0	0	13	5,630	5,330	9	1	0	x	y		32.1	26.8	28.1	0.9	M
51	0	9	0	0	9	2,200	2,050	0	9	0	x	x		31.4	31.4	31.4	x	P
DEPLETED FIELDS																		
52	0	0	0	0	0	1,020	880	0	0	0	250	0	0	Gas only				
53	0	0	0	0	0	420	395	0	0	0	x	x	x	28	26	27	0.3	P
54	0	0	0	0	0	875	825	0	0	0	x	0	0	20	18	19	0.6	P
55	0	0	0	0	0	3,767	x	0	0	0	x	0	0	32	32	32	0.3	P
56	0	0	0	0	0	2,870	2,820	0	0	0	x	0	0	40	40	40	0.3	P
57	0	0	0	0	0	2,940	2,885	0	0	0	x	0	0	37	37	37	0.3	P
58	0	0	0	0	0	3,780	3,765	0	0	0	x	0	0	32	32	32	0.2	P
59	0	0	0	0	0	1,820	1,535	0	0	0	x	0	0	31.5	31.5	31.5	0.4	P
60	0	0	0	0	0	1,160	1,000	0	0	0	x	0	0	34.5	33.9	34.2	0.4	P
61	0	0	0	0	0	1,460	1,440	0	0	0	x	x	x	34	32	33	0.4	P
62	0	0	0	0	0	1,900	1,400	0	0	0	x	x	x	34.8	33.8	34.4	0.2	P
63	0	0	0	0	0	757	720	0	0	0	x	x	0	34	34	34	0.4	P
64	0	0	0	0	0	6,232	5,900	0	0	0	x	x		39	39	39	0.4	P
65	56	4,243	0	106	4,405			24	4,268	1								

Line Number	Character of Gas, Approx. Average during 1936		Producing Rock						Number of Dry and/ or Near-dry Holes to End of 1936	Deepest Zone Tested to End of 1936	
	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Name	Age ^f	Character ^g	Porosity ^h	Net Thickness, Average in Feet	Structure ⁱ		Name	Depth of Hole, Ft.
49	x	1.5	Crevice-Top Austin	CreU	C	x	x	F	1	Austin chalk	2,450
40	x	x	Austin chalk	CreU	C	x	x	N	2	Austin chalk	5,850
51	x	x	Crevice-Top Austin	CreU	C	x	x	F	5	Edwards	2,600
DEPLETED FIELDS											
52	1,110	1.8	Taylor sand	CreU	Ss	x	13	A	7	Woodbine	3,057
53	1,120	1.3	Navarro sand	CreU	SH	18	25	F	15	Glenrose	3,550
54	1,040	1.6	Nacatoch	CreU	Ss	14	19	AF	25	Woodbine	3,480
55	x	x	Unknown	x	x	x	x	Crev.	22	Glenrose	6,050
56	x	x	Woodbine	CreU	Ss	25	15	F	35	Woodbine	3,509
57	x	x	Woodbine	CreU	SH	25	10	F	9	Woodbine	3,310
58	x	x	Taylor sand	CreU	S	x	15	F	3	Edwards	4,281
59	x	x	Serpentine	CreU	P	12	x	Intn.	12	Edwards	2,050
60	x	x	Buda-Georgetown	CreL	L	20	20	AF	8	Glenrose	1,409
61	x	0.3	Taylor sand	CreU	S	13	10	F	7	Edwards	2,250
62	1,120	1.5	Serpentine	CreU	P	13	x	Intn.	8	Austin chalk	2,001
63	x	0.4	Serpentine	CreU	P	15-25	x	Intn.	3	Taylor marl	850
64	x	x	Buda limestone	CreL	L	x	x	N	0	Edwards	6,512
65									1,979		

^a Footnotes to column heads and explanation of symbols are given on page 291.

PRODUCTION

The acid treatment of calcareous formations in the Central Texas area, while not spectacular, was sufficiently successful to be called profitable. In the Pearsall-Austin chalk field acid treatment was used in conjunction with "shooting," for the most part at the time of completion. In the fault-line fields it was learned by some operators that a period of production before acidation made the treatment more effective.

TABLE 2.—Summary of Drilling Operations in the Central Texas Area

Important Wildcats Drilled in 1936

	County	Location		Total Depth, Ft.	Surface Formation
		Survey	No.		
1	Frio.....	A. Lynch	321	5655	Claiborne
2	Zavalla.....	A. B. & M.	43	7082	Claiborne
3	Kimble.....	Brooks & Burleson	15	3285	Edwards
4	Zavalla.....	A. B. & M.	1	5756	Claiborne
5	Zavalla.....	Clemente Bastillio	1	6020	Claiborne
6	Fayette.....	Samuel Millet	1	7141	Yegua
7	Burleson.....	Eliza Santo	210	6241	Crockett
8	Edwards.....	G. C. & S. E.	2	5270	Edwards
9	Limestone.....	x	x	6064	Wileox-Midway
10	Freestone.....	x	x	4515	Wileox-Claiborne
11	Navarro.....	x	x	4220	Taylor

Important Wildcats Drilled in 1936

	Deepest Horizon Tested	Drilled by	Initial Production per Day	Choke, Fractions of an In.	Pressure, Lb. per Sq. In.		Remarks
			Oil, U. S. Bbl.		Casing	Tubing	
1	Austin chalk	Amerada-Rycade	2629	1	1250	500	Pearsall Austin chalk discovery.
2	Edwards limestone	Bay Oil Corporation					10-ft. porosity in Edwards
3	Ellenberger	Wileox Oil Co.					Dry in sandy lime.
4	Austin chalk	Frank Buttram et al.					Dry in Austin chalk.
5	Austin chalk	Leona Oil and Gas Co.					Dry in Austin chalk.
6	Edwards limestone	P. C. Teas et al.					Show of oil and gas.
7	Edwards limestone	Red Bank Oil Co.					Salt and sulphur water.
8	Pennsylvanian	P. C. Teas—Helmerich and Payne					Abandoned dry.
9	Trinity	C. F. Lytle et al.					Salt water with shows of oil and gas.
10	Woodbine sand	R. H. Wheelock et al.					Dry in Woodbine.
11	Trinity	Groginski & Bateman					No shows. Abandoned.

Number of wells drilling Dec. 31, 1936.....	83
Number of oil wells completed during 1936.....	127
Number of gas wells completed during 1936.....	8
Number of dry holes completed during 1936.....	212

Shooting was found to be effective in the Pearsall-Austin chalk field. Shooting both previous to and following acid treatment was employed with no definite conclusion as to which procedure was the more effective.

Experiments were continued with large-capacity casing pumps but, as yet, there has been no marked tendency to break away from standard equipment. As new wells are found with high fluid levels there is expected to be an increase in the number of casing pumps used.

While many failures were drilled in 1936 it is expected that the Austin chalk will be thoroughly explored for reserves throughout the Central Texas area during 1937. To date the Pearsall field is the only one producing from a known Austin chalk reservoir, the production in other Austin chalk fields being found in crevices.

ACKNOWLEDGMENT

Acknowledgment for assistance in gathering the data and information contained in this report is gratefully made to the following: V. E. Cottingham, Director of Petroleum for the Railroad Commission of Texas; W. K. Esgen, Division Geologist for the Humble Oil and Refining Co. at Corpus Christie, Tex.; Paul R. Martin, Chief Scout for the Pure Oil Co.; Jesse L. Bullard, Shell Petroleum Corporation; Gil Thorne, The Texas Company; H. L. Mann, The Texas Gas Utilities Co.; J. H. Dunn, Production Engineer for The Lone Star Gas Co.; and O. R. Champion, The Amerada Petroleum Corporation.

The writer is also indebted to C. V. Millikan and R. S. Christie, of the Amerada Petroleum Corporation, for direction in planning and preparing the report.

TABLE 3.—*Accumulated Production from Central Texas Area by Geologic Zones*

Geologic Zone	First Development		Total Acres	Accumulated Production, Bbl.
	Year	Field		
Woodbine sand.....	1920	Mexia	8,350	241,489,511
Edwards limestone.....	1921	Luling	5,075	139,609,320
Navarro-Taylor-Midway.....	1896	Corsicana	26,380	33,343,923
Serpentine.....	1914	Thrall	4,402	18,926,575
Austin chalk.....	1930	Dunlap	1,645	869,932
Buda and Georgetown.....	1922	Chilton	90	115,057
Walnut clay (Paluxy).....	1902	South Bosque	2,500	88,830
Unknown (Kosse well).....	1922	Kosse	10	33,000
Total.....			48,452	434,476,148

Development and Production in the East Texas District

BY WALLACE RALSTON*

(New York Meeting, February, 1937)

THE East Texas district includes the northeast 38 counties of the State of Texas. It still remains one of the most important oil-and-gas-producing areas of the United States, since it includes within its boundaries the large East Texas field. Other fields of importance are: Van, Rodessa, Talco, Cayuga, Long Lake and Sulphur Bluff. Production is from the Nacatoch, Blossom, and Woodbine of the upper Cretaceous and the Paluxy and Glen Rose of the lower Cretaceous. Of these, the Woodbine is the most important, since it is the producing horizon in the East Texas field.

FIELDS

East Texas Field.—There were 2471 oil wells, 1 gas well and 84 failures completed during the year of 1936 in the East Texas field; that is, 1565 fewer than in the year of 1935. The total number of producing wells is now 22,031, of which 50 are temporarily shut down; 18,435 wells flowing their production; 3150 pumping; 293 on gas-lift, and 82 operated by other methods. This shows an increase of 1642 wells on artificial lift over Jan. 1, 1935. The average daily salt-water production is estimated at 42,700 bbl. from 2327 wells—an increase of 1201 wells over the year of 1935. The field is now drilled to an average density of one well to 5.85 acres. Average bottom-hole pressure has dropped from 1193 lb. to 1168 lb., approximately 1 lb. drop for each 6,600,000 bbl. of oil produced. During the month of December 1936, the estimated daily average production of illegal oil had dropped from 20,500 bbl. in December 1935 to 7500 bbl. The commercial gas production is of minor importance in the East Texas field, and figures for the amount of gas taken from the field are not available at the present time.

Talco Field, Titus and Franklin Counties.—The discovery well was drilled by Housh, Thompson et al. on the C. M. Carr tract and completed in March 1936, as a pumping well making 552 bbl. per day of 24° gravity oil. This well was first completed at a total depth of 4208 ft., the top of the sand being 4190 ft. Later it was deepened to 4260 ft., which increased the production from 552 to 725 bbl. per day. This field is producing

Manuscript received at the office of the Institute Feb. 17, 1937.

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from the Paluxy sand zone of Lower Cretaceous age. This is the first commercial production to be obtained from the Paluxy horizon in the State of Texas. Up to the first of the year, 177 oil wells and 13 dry holes had been completed. The structure is an east-west trending fault, approximately 8 miles long and upthrown on the south side. This fault lies on the northern extension of the Mexia-Powell fault zone, about 100 miles northeast of the Powell field, previously the most northerly production on this fault zone. Powell is producing from the Woodbine sand and Talco has been tested dry, in this same formation. Estimated proven acreage is about 10,000 acres. Preliminary estimates of ultimate production vary from 100,000,000 to 120,000,000 bbl. Approximately 40 per cent of the wells are completed as flowing wells, the rest being pumpers. Very little gas is present, and it is believed that there will be sufficient water drive to flush the oil from the sand.

Sulphur Bluff Field, Hopkins County.—The discovery well was drilled by Hager, Luce and Russ Petroleum Co. on the J. E. Worsham tract, near the small town of Sulphur Bluff, in the north central part of Hopkins County. The well was completed as a pumping well, making 530 bbl. of oil per day from the Paluxy sand, at a total depth of 4500 ft. This field, like Talco, is a faulted structure and is on the same fault zone. Accumulation is on the southeast or upthrown side of the fault. Owing

TABLE 1.—Oil and Gas Production in East Texas District

Line Number	Field, County	Age, Years to End of 1936	Area Proved, Acres			
			Oil	Oil and Gas ^a	Gas	Total
1	Caddo, Marion.....	32	980			980
2	Bethany, Panola.....	18			21,000	21,000
3	Waskom, Harrison.....	12			7,500	7,500
4	Boggy Creek, Anderson, Cherokee.....	9¾	200			200
5	Van, Van Zandt.....	7	4,527			4,527
6	Van (shallow), Van Zandt.....	4	200			200
7	East Texas, Rusk, Gregg, Smith, Upshur, Cherokee.....	6½	127,000		2,000	129,000
8	Long Lake, Anderson, Leon.....	3½	1,000		9,000	10,000
9	Cayuga, Anderson, Henderson, Freestone.....	2¾	3,000		9,000	12,000
10	Shell ¹ , Leon.....	3			6,000x	6,000x
11	Kittrell, Houston.....	2½	160			160
12	Camp Hill, Anderson.....	2	500			500
13	Rodessa, Cass.....	1	4,200	x	4,000x	8,200x
14	Rusk, Cherokee.....	2½	200x			200x
15	Talco, Titus, Franklin.....	¾	10,000			10,000
16	Sulphur Bluff, Hopkins.....	½	1,500			1,500
17	Grapeland ¹ , Houston.....	½	x	x	x	x
18	Joaquin ¹ , Shelby.....	¼	x	x	x	x
19	Carthage ¹ , Panola.....	½	x	x	x	x

^a Footnotes to column heads and explanation of symbols are given on page 291.

¹ Not enough development to base reasonable estimates.

to the steep dip of the producing formation, it is estimated that the producing area will be smaller than at Talco. Proven acreage is estimated to be about 1500 acres. Preliminary estimates of ultimate oil recovery vary from 20,000,000 to 25,000,000 bbl. The oil produced in Sulphur Bluff is of low gravity similar to that in the Talco field. Up to Jan. 1, 1937, only 12 wells had been completed.

Rodessa Field, Cass County.—The first oil well of the Rodessa field completed in Texas was drilled in December 1935. Since that time it has been proved that the larger part of the Rodessa field lies in Texas. During the past year, 169 wells were completed, 159 being oil wells, 2 gas wells, and 6 dry holes. Rodessa produced 3,139,641 bbl. of oil during 1936. It is very difficult to give an accurate figure on the amount of gas produced with the oil in this field, as large quantities of it are blown into the air, while making the oil production. The crest of the structure produces only gas, while the flanks produce oil. Wells located on the border line between the oil and gas areas have very high gas-oil ratios. Some of the wells in the Louisiana side of the field have gas-oil ratios as high as 120,000 cu. ft. to a barrel. The average bottom-hole pressure has dropped from 2800 lb. to 1967 lb. during the year. Structurally this field is a northeast-southwest trending fault, extending approximately 15 miles across the north flank of the Sabine uplift. Production is limited to the north or upthrown side of the fault. During the year of 1936, the United Gas Co. took 2.5 million cubic feet of gas from this field.

TABLE 1.—(Continued)

Line Number	Total Oil Production, Bbl.				Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells		
	To End of 1936	During 1935	During 1936	Daily Average during Nov. 1936	To End of 1936	During 1935	During 1936	Maximum Daily during 1936	Completed to End of 1936	During 1936	
										Completed	Abandoned
1	7,559,596	32,077	29,676	81	108,019	6,044	4,491	12	79	1	
2					44,451	1,817		5	y		
3					6,756		1,878		y	6	
4	4,497,758	203,556	190,398	446					33		
5	99,453,662	13,965,500	12,514,585	29,349					556	49	1
6	157,957	56,283	61,867	151					30	6	1
7	985,015,980	174,200,150	165,270,636	451,598					22,031	2,471	y
8	528,710	94,974	381,743	1,183	7,846	2,631	5,215	y	33	18	
9	4,032,273	1,294,128	2,156,095	6,511	5,988.5	623.5	5,365	y	170	62	
10									3		
11	755,919	369,640	345,887	751					13		1
12	258,779	125,993	132,786	176					10	2	2
13	3,152,700	13,059	3,139,641	20,975	2.5		2.5	y	162	161	
14	184,906	79,215	67,705	150					3		
15	1,325,816		1,325,816	9,235					178	178	
16	40,856		40,856	679					12	12	
17									1	1	
18									1	1	
19									1	1	

Van Field, Van Zandt County.—During 1936 there were 55 wells completed in the Van field, 49 in the Woodbine area and 6 in the Nacatoch sand area. This makes a total of 546 wells producing in the Woodbine area, and of these 355 are flowing their production and 191 are pumping. There are 30 producing wells in the Nacatoch sand area, all of which are pumping their production. The production from the Nacatoch sand area is of small economic importance. The total production for both areas during the year of 1936 was 12,576,452 bbl., which is 1,445,331 bbl. less than during the year of 1935. This decrease in production is due to proration and not to the depletion of the field. Bottom-hole pressure dropped from 1168 to 1162 lb.—an average drop of 1 lb. in pressure for each 2,100,000 bbl. of oil produced.

Long Lake Field, Anderson County.—During the year, 15 oil wells, 2 gas wells and 1 dry hole were completed in the Long Lake field. This increased the yearly oil production from 94,974 bbl. in 1935 to 381,743 in 1936. The volume of gas produced increased from 2631 million cubic feet in 1935 to 5215 million in 1936. As of Dec. 31, 1936, there were 33 producing wells in this field, 18 being oil wells and 15 gas wells, all of which are flowing their production.

Cayuga Field, Anderson County.—During the year, 62 wells were completed in this field, 57 being oil wells and 5 gas wells. Oil production was increased from 1,294,128 bbl. in 1935 to 2,156,095 bbl. in 1936. Gas

TABLE 1.—(Continued)

Line Number	Number of Oil and/or Gas Wells				Depth, Average in Feet		Oil Production Methods at End of 1936				Pressure, Lb. per Sq. In. ^d		Character of Oil, Approx. Average during 1936			
	At End of 1936				Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells				Initial	Average at End of		Gravity A.P.I. at 60° F., Weighted Average	Sulphur Per Cent	Base ^e
	Temporarily Shut Down	Producing Oil Only	Producing Gas Only	Total Producing			Flowing	Pumping	Gas-lift	Miscellaneous		1935	1936			
1		32		32	2,366	2,300		31			x	x	x	40	y	P
2			146	146	4,700 ²	1,000 ²					y	y	y			
3			88	88	4,650	1,000					y	y	y			
4		21		21	3,666	3,632		21			650			38.5	0.24	P
5	7	546		546	3,000	2,500	355	191			e1,250	e1,168	e1,162	34	0.8	P
6		30		30	1,200	1,130		30						31	1.16	P
7	50	21,960	21	21,981	3,665	3,632	18,435	3,150	293	82	e1,600±	e1,193	e1,168	39	0.25	M
8		18	15	33	5,275	5,178	32			1	y	y	y	43	0.24	P
9		144	26	170	4,085	3,822	160	4		6	y	y	y	29	1.7	A
10					5,285	5,695										
11		12		12	2,013	1,995		12			700			23.8	0.1	P
12		8		8	5,110	5,100		8			e1,962			38	0.36	P
13		158	4	162	6,020	5,960	160	2			e2,800		e1,967	43	0.18	P
14	1			2	5,125	5,120		2			y			42	y	P
15	1	177		177			72	105						22	2.8	M
16		12		12	4,520	4,480	5	7			y	y	y	22	2.8	M
17	1				x	x					2,200					
18	1				x	x					2,400x					
19	1				x	x					1,850					

² Figure for top and bottom of producing zones are from the top of the highest pay to bottom of lowest pay; six or more horizons are present in this interval.

production was increased from 623.5 million cubic feet to 5365 million cubic feet during the same period. This field now has 170 producing wells, 144 being oil wells and 26 gas wells. As of Dec. 31, 1936, there were 160 flowing wells, 4 pumping wells and 6 wells being operated with flow valves. The Tidewater Oil Co. and the Seaboard Oil Corporation drilled their second Trinity test about 2 miles southwest of their first test¹. This test was completed at a total depth of 7570 ft. in the lower Glen Rose of lower Cretaceous age. The well flowed 16 bbl. of distillate and 11,925,000 cu. ft. of gas on an 8-hr. test through 1/4-in. and 1/8-in. tubing chokes and 1/2-in. and 3/8-in. casing chokes.

Other Areas.—The other fields in this district—Caddo, Bethany, Waskom, Boggy Creek, Kittrell, Camp Hill and Rusk—were extremely quiet, very few wells being drilled and no new horizons being added.

EXPLORATORY DRILLING

There were 77 failures in the East Texas district during 1936; that is, 129 fewer than during 1935. The main reason for the decrease of wildcat activity was the discovery of Talco, Sulphur Bluff, and the extension of Rodessa into Cass County, Texas. The development of these fields used most of the drilling rigs that were capable of drilling deep tests. This exploratory drilling discovered, besides Talco and Sulphur Bluff, three gas-distillate fields, as follows: Grapeland field, in the north central

TABLE 1.—(Continued)

Line Number	Character of Gas, Approx. Average during 1936		Producing Rock						Deepest Zone Tested to End of 1936		
	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Name	Age ¹	Character ²	Porosity ³	Net Thick- ness, Average in Feet	Structure ⁴	Number of Dry and/ or Near-dry Holes to End of 1936	Name	Depth of Hole, Feet
1			Tokio	CreU	S	20±	15	A	y	y	y
2	1,000	y	Various zones	CreU & L	S & L	y	z	A	39y	Sub-anhydrite CreL	5,860
3	1,000	y	Various zones	CreU & L	S & L	y	z	A	16y	Glen Rose CreL	4,980
4			Woodbine	CreU	S	25	± 34	DS	43	Fredericksburg	4,648
5			Woodbine	CreU	SH	25	268	DS	66	Trinity CreL	7,501
6			Nacatoch	CreU	S	z	20	AF	11	Trinity CreL	
7		23	Woodbine	CreL	S	25	30	MU	302	Washita CreL	3,894
8	y	y	Woodbine	CreL	S	24	62	A	1	Woodbine CreU	5,468
9	y	y	Woodbine	CreU	S	24	75	A	2	Travis Peak CreL	9,085
10			Woodbine	CreU	S	11	30	A	2	Washita CreL	6,140
11			Reklaw	Eocene	S	y	12	DS	9	Wilcox Eocene	3,870
12			Sub-Clarkville and Woodbine	CreU	S	23	5	AF	4	Glen Rose CreL	8,383
13	y	y	L. Glen Rose	CreL	L	± 17	15	AF	6	Travis Peak	7,010
14			Woodbine	CreU	S	20	5	MU	3	Woodbine	5,302
15			Paluxy	CreL	S	20	50	AF	13	Paluxy	
16			Paluxy	CreL	S	20	40	AF		Paluxy CreL	4,577
17			Woodbine	CreU	S	24	z	A		Woodbine CreU	6,033
18			Glen Rose	CreL	L	z	z	AF?		Glen Rose CreL	5,029
19			Glen Rose	CreL	L	z	z	A?		Glen Rose CreL	6,002

¹ See *Trans. A.I.M.E.* (1936) 118, 367.

part of Houston County, approximately one mile north of the town of Grapeland; Joaquin field, in the northeastern part of Shelby County, near the small town of Joaquin; and the recent discovery 6 miles east of Carthage, in Panola County. These gas-distillate discoveries may prove to be substantial oil-producing fields, but to date there has not been sufficient development to predict their extent and economic importance.

The Grapeland field was discovered July 16, 1936. The discovery well was drilled by Ellison, McBride, Haberle and Thornton, on the J. E. Bean tract, and completed in the Woodbine sand at a total depth of 6037 ft. The initial test showed the well to be capable of producing at least 50,000,000 cu. ft. of gas per day with a large amount of distillate. This discovery is very important, as it extends the area of possible Woodbine production approximately 15 miles southeast of any previous Woodbine production.

TABLE 2.—*Summary of Drilling Operations in East Texas*

Important Wildcats Drilled in 1936					
	County	Survey	Total Depth, Ft.	Surface Formation	Deepest Horizon Tested
1	Titus.....	Delgado	4260	Midway Eocene	Paluxy CrL
2	Houston.....	Steadman	6033	Mt. Selman Eocene	Woodbine CrU
3	Hopkins.....	Wetmore	4500	Midway Eocene	Paluxy CrL
4	Shelby.....	Henry	5029	Wilcox Eocene	Glen Rose CrL
5	Panola.....	Potts	6002	Wilcox Eocene	Glen Rose CrL
6	Rusk.....	Elliot	7799	Mt. Selman Eocene	Travis Peak CrL

Important Wildcats Drilled in 1936							
	Drilled by	Initial Production per Day		Choke, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
		Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
1	Housh, Thompson & Hinton	726			Pump		Discovery Talco.
2	Ellison, McBride et al.		23½	¾	1800	2200	Discovery Grapeland.
3	Hager, Luce & Russ	530			Pump		Discovery Sulphur Bluff.
4	H. A. Stebbinger		4	½	½	½	Discovery Joaquin.
5	A. C. Glassell		3½	¼	1850	1750	Discovery Carthage.
6	Pure Oil Co.						Failure.

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1936.....	158	21
Number of oil wells completed during 1936.....	2891	2
Number of gas wells completed during 1936.....	12	4
Number of dry holes completed during 1936.....	111	77

Joaquin field is in the northeast corner of Shelby County. The discovery well was drilled on the Pickering Lumber Co. tract, by H. A. Stebbinger. Initial gauge of the well, at a total depth of 5029 ft., was estimated between 5 and 10 million cubic feet of gas and a small amount of distillate. The producing horizon is in the lower Glen Rose of lower Cretaceous age.

Carthage Field.—The recently completed gas-distillate well, 6 miles east of Carthage, in Panola County, was drilled on the Frost Lumber Co. tract, by A. C. Glassell. This well was completed in the lower Glen Rose at a total depth of 6002 ft., making approximately 4 million cubic feet of gas and some distillate.

The gas-distillate wells, which have recently been completed in the lower Glen Rose formation, revive hope for production from this same formation on other well-known structures that have been proved dry in the upper Cretaceous formations.

Another important test drilled in this district during the year of 1936 was drilled by the Pure Oil Co. on the Faulkner tract, in the south central part of Rusk County. This well failed to obtain any commercial production, although it tested the Glen Rose and possibly the upper 300 ft. of the Travis Peak formation. Although the well is on a large faulted structure on the southwest flank of the Sabine uplift, it did not encounter any good porosity in the Glen Rose or Travis Peak.

Approximately 170,000,000 bbl. of new reserves were added to the district during 1936. Because of the size of the East Texas field, these new reserves did not equal the total production for the district, which was 185,657,691 bbl. Of this total the East Texas field produced over 165,000,000 barrels.

SUMMARY AND OUTLOOK FOR 1937

The East Texas field should be fully developed during the year. Rodessa, Talco, and Sulphur Bluff should be outlined and mostly developed. Several very important exploratory locations have been proposed for the coming year.

ACKNOWLEDGMENTS

Various sources were used in compiling the data used in this report. Average figures have been used on areas where it is difficult to obtain accurate information. Thanks for information are due to many persons, but especially to Mr. Frank E. Poulsen, Pure Oil Co., for data on the Van field, and to Mr. M. Schwartz, of the Seaboard Oil Corporation, for data on Cayuga and Long Lake fields, and to Mr. C. R. McKnight, of the Arkansas Louisiana Gas Co., for data on the Waskom and Bethany gas fields; also to various members of the Sun Oil Company's technical staff for other data.

Oil and Gas Production on the Texas Gulf Coast during 1936

BY W. V. VIETTI,* MEMBER A.I.M.E., AND E. P. HAYES

OPERATIONS on the Texas Gulf Coast during 1936 increased materially over 1935. A number of new fields were discovered and a few of the older fields were extended, both by the discovery of deeper pay sands and by lateral expansion of the known producing horizons. Twenty-seven new fields have been discovered, of which 25 are oil fields and the others are gas fields that have every indication of becoming oil-producing areas. Amelia, Anahuac, Bay City, North Pettus, Placedo, Pickett Ridge and Tomoconnor have had major extensions.

Production for 1936 amounted to 91,224,844 bbl., an increase of 21,627,033 bbl., or 31 per cent, over the 1935 production of 69,597,811 bbl. The number of producing wells at the end of 1936 was 6727, as compared with 4851 at the end of 1935. Proration has continued in force, thus decreasing the rate of depletion and the number of abandonments normally expected.

NEW FIELDS

A brief discussion of the new fields follows, in addition to Tables 1 and 2, which contain the general data on these fields.

Aransas (McC Campbell).—Buckingham and McC Campbell No. 1 McC Campbell was drilled to 7501 ft., then plugged back to 6560 ft. and completed in the Marginulina for a 100-bbl. flowing well on July 18.

Bee County.—The Voss field, discovered by Swiger and Devonian's No. 1 Voss, and the Holzmark field, discovered by Miller and Donzis on the Holzmark farm, are both of the same type structurally and are caused by folding against a fault, one field being on one side of a fault and the other on the opposite side of the same fault.

Brooks County.—Standard Oil Company of Texas Garcia No. 1, the discovery well in the Alta Mesa field, and Dick Young's Singer No. 1, the discovery well of Alta Verde, appear to indicate small fields. Garcia No. 1 was drilled to 8022 ft. and plugged back to 2485 ft., at which depth the well made 189 barrels.

Lockridge.—This gas field was discovered by Gulf Production Company's Fairfield No. 1, in Brazoria County. It was originally drilled to

Manuscript received at the office of the Institute March 11, 1937.

* Producing Department, The Texas Company, Houston, Texas.

TABLE 1.—Oil and Gas Production in Texas Gulf Coast

Line Number	Field, County	Age, Years to End of 1936	Area Proved, Acres				Total Oil Production, Bbl.		
			Oil	Oil and Gas ^a	Gas	Total	To End of 1936	During 1935	During 1936
1	Spindletop, Jefferson.....	36	430	0	0	430	123,023,474	948,357	844,684
2	Shallow.....	36	280			280	50,949,388	115,000	102,500 ¹
3	Deep.....	11	150			150	72,074,086	833,357	742,184 ¹
4	Saratoga, Hardin.....	36	538	0	0	538	28,102,048	317,698	366,057
5	Sour Lake, Hardin.....	35	946	0	0	946	77,985,875	611,983	572,165
6	Batson, Hardin.....	34	597	0	0	597	37,613,457	616,343	653,484
7	Big Hill, Matagorda.....	33	15	0	0	15	210,906	(Prod. Depleted 1907)	
8	Hoskins Mound, Brazoria.....	33	10	0	0	10	81,755	(Prod. Depleted 1907)	
9	Humble, Harris.....	32	2,400	0	0	2,400	121,335,873	1,242,994	1,196,159
10	Shallow.....	32	2,200			2,200	108,971,447	650,000	569,200 ¹
11	Deep.....	8	200			200	12,364,426	592,994	626,959 ¹
12	North Dayton, Liberty.....	32	55	0	0	55	2,252,936	56,120	45,939
13	Shallow.....	32	25			25	800,000	0	0
14	Deep.....	9	30			30	1,452,936	56,120	45,939
15	Goose Creek, Harris.....	29	910	0	0	910	75,250,559	1,048,987	978,726
16	Markham, Matagorda.....	29	300	0	0	300	5,911,013	468,566	567,389
17	Orange, Orange.....	24	400	0	0	400	32,009,228	261,833	247,344
18	Brenham, Austin and Washington	22	55	0	0	55	339,008	4,896	9,117
19	Damon Mound, Brazoria.....	22	270	0	0	270	9,195,351	197,979	179,215
20	West Columbia, Brazoria.....	22	350	0	0	350	79,463,495	872,560	788,095
21	Barbers Hill, Chambers.....	21	515	0	0	515	55,561,179	6,780,982	5,471,266
22	Shallow.....	21	70			70	1,735,214	0	0
23	Deep.....	9	445			445	53,825,965	6,780,982	5,471,266
24	Hull, Liberty.....	19	750	0	0	750	81,937,727	2,320,564	1,956,507
25	Shallow.....	19	650			650	77,441,748	1,256,822	1,079,311
26	Deep.....	4	100			100	4,495,979	1,063,742	877,196
27	Blue Ridge, Fort Bend.....	18	325	0	0	325	10,220,815	335,328	526,740
28	Pierce Junction, Fort Bend.....	16	320	0	0	320	29,580,441	1,177,255	1,293,178
29	Edna, Jackson.....	16	0	20	105	125	0	0	0 ²
30	Big Creek, Fort Bend.....	15	200	0	0	200	8,983,950	355,126	392,975
31	High Island, Galveston.....	15	200	0	0	200	13,112,306	2,521,916	2,066,254
32	Stratton Ridge, Brazoria.....	15	25	0	0	25	12,214	(Prod. Depleted 1933)	
33	Big Hill, Jefferson.....	14	10	0	0	10	13,853	(Prod. Depleted 1924)	
34	Hockley, Harris.....	14	10	0	0	10	23,404	(Prod. Depleted 1935)	
35	Mathis, Live Oak and San Patricio	13	0	0	100	100			
36	Boling, Fort Bend and Wharton	12	200	0	0	200	5,065,712	183,925	347,871
37	South Liberty, Liberty.....	12	344	0	0	344	15,054,602	199,868	231,740
38	Kingsville, Kleberg.....	11	90	0	175	265	660,352	22,994	21,659
39	Nash, Brazoria and Fort Bend....	11	120	0	0	120	1,651,574	13,816	14,313

^a Footnotes to column heads and explanation of symbols are given on page 291.¹ Estimated.² Production used to develop field.

TABLE 1.—(Continued)

Line Number	Total Oil Production, Bbl.	Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells								Depth, Average in Feet
		To End of 1936	During 1935	During 1936	Maximum Daily during 1936	Completed to End of 1936	During 1936		At End of 1936					
							Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas ^b	Producing Gas Only	Total Producing	
1	2,071					1,346	3	1	133y	146			146	{ 750 1,200 2,920 5,900 1,000
2	1,621 ¹					1,002	0	y	y	y			y	
3	450 ¹					344	3	y	y	y			y	
4	884					757x	18	3	17	222			222	
5	1,568					780x	1	y	46	185			185	{ 900 1,250 5,000
6	1,487					996x	12	2	6	202			202	
7						3								862
8						6								623
9	3,036					1,685	5	0	1	257			257	{ 700 ^a 5,670
10	y					1,591	0	0	y	y			y	
11	y					94	5	0	y	y			y	5,670
12	116					62	0	0	4	7			7	3,800
13	0					52	0	0	0	0			0	1,200
14	116					10	0	0	4	7			7	4,800
15	2,385					866	5	3	y	82			82	{ 1,000 4,600
16	1,836					139	9	3	y	33			33	{ 530 3,800
17	699					315	1	4	16	46			46	4,000
18	20					62	y	y	y	29y			29y	225
19	430					128	6	3	y	32			32	2,700
20	2,003					236	3	4	4	32			32	3,200
21	12,157					398	24	26	7	162			162	4,500
22	0					42	0	0	0	0				2,300
23	12,157					356	24	26	7	162				5,200
24	5,376					732	19	10	12	179			179	2,900
25	3,165					624	10	0	y	y			y	2,200
26	2,211					108	9	10y	y	y				4,650
27	1,095					180	13	7	0	52		1	53	3,600
28	3,986					248	21	13	4	76			76	{ 3,800 4,800
29	0	y	y	y	y	12	1	y	y	1y			1y	4,655
30	947					76	6	y	1	24			24	3,850
31	3,249					97	10	3	15	53		1	54	{ 4,600 6,200 4,360
32						4								2,500
33						3								2,250
34						3								
35		y	y	y	y	5		y				y	y	2,385
36	1,059					156	6	16	y	71		1	72	1,375
37	682					322	4	4	0	51			51	3,500
38	58					19	0	y	y	9		3	12	2,350
39	51					24	0	0	y	1			1	4,300

³ Cap rock.

TABLE 1.—(Continued)

Line Number	Depth, Average in Feet	Oil Production Methods at End of 1936				Injection into Reservoir	Pressure, Lb. per Sq. In. ^d		Character of Oil, Approx. Average during 1936				Character of Gas, Approx. Average during 1936				
		Number of Wells					Initial	Average at End of		Gravity A.P.I. at 60° F.				B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.		
		Flowing	Pumping	Gas-lift	Air-lift			1935	1936	Maximum	Minimum	Weighted Average	Sulphur, Per Cent			Base	
1	600	4	142			G-1		50	50			26	0.24	A			
2							x			x	x	25		A			
3							400±			29	23	26		A			
4			222				x			22	16	20	y	A			
5		13	172				x			31	16	20	y	A			
6		5	196	1			x			40	20	27.7	y	A			
7							x			x	x	x	x	A			
8							x			x	x	x	x	A			
9		6	251				x			52	18	26.5	0.11	A			
10																	
11																	
12			7			400					41.5	22	28	0.12	A		
13					x						24						
14											36						
15			82								30	20	23.5	0.19	A		
16		8	25			x				27.6	23	23.2	0.21	A			
17		1	45			x				27.4	20.4	23.8	0.18	A			
18			29y							19	14	17	y	A			
19		1	31			x				33	21	26	0.37	A			
20		1	29		2					32	18	28	y	A			
21		46	103	13						34	24.8	26	0.21	A			
22	{ 3,780 4,780 4,640					x											
23		46	103	13		296	877	e1,565	34	24.8	26	0.21	A				
24		7	172						41	17	32.7	0.28	A				
25		2	118			x			38	15.5	30						
26			5	54			530			41	36	38					
27		2	50			385			45	20	26	0.25	A				
28		26	50			355				41.5	21	27.6	0.17	A			
29		1y				y				y	y	y	y	y		y	
30		1	23			400				42.7	19.5	28	y	A			
31		15	37	1		527				39	23	33	y	A			
32						x						29	x	A			
33						x						x	x	A			
34	2,220					40				37	22	32	x	A			
35	2,375					935									y	y	
36		36	35							33.7	21.3	28.3	0.41	A			
37		2	49			50				47	20.5	24	0.18	A			
38	2,050	2	7									21.5	0.14	A			
39			1			800						19.9	y	A			

TABLE 1.—(Continued)

Line Number	Producing Rock						Deepest Zone Tested to End of 1936	
	Name	Age ^f	Character ^g	Porosity ^h	Net Thickness, Average in Feet	Structures ⁱ	Number of Dry and/or Near-dry Holes to End of 1936	Depth of Hole, Ft.
1							126	Vicksburg
2	Cap rock, Pli	{ Per-Ter, Pli	{ L SH	{ Cav Por	<i>z</i>	Ds	18	
3	Mio, Mid-Olig, Frio	Mio, Olig	Ss	Por	69		108	
4	{ Lagarto, Mid-Olig, Cap rock	{ Mio, Pli, Olig, Pre-Ter	Ss, L	Por	<i>z</i>	Ds	217 <i>z</i>	Yegua
5	{ Cap rock, Pli, Mio, Mid-Olig, Jackson, U. Saline Bayou	{ Pre-Ter, Pli, Mio, Olig, Eoc	{ L, Ss, SH	{ Cav Por	<i>z</i>	Ds	190	Yegua
6	{ Cap rock, Lissie, Lagarto, Mid-Olig, Yegua	{ Pre-Ter, Pli, Mio, Olig, Eoc	L, Ss	{ Cav Por	74 <i>z</i>	Ds	83 <i>z</i>	Crockett
7	Cap rock, Mio	Pre-Ter, Mio	L <i>z</i>	{ Cav Por	<i>z</i>	Ds	5	3,000 <i>z</i>
8	<i>y</i>		SH	Por	<i>z</i>	Ds	39	Salt
9						Ds	810	Cook Mt.
10	Cap rock, Mio Olig	{ Pre-Ter, Mio, Olig	L, S	{ Cav Por	<i>z</i>			
11	{ Mid-Olig, Jackson, Cockfield, Yegua	Olig, Eoc	SH	Por	400			
12						Ds	109	Yegua
13	Pli, Mio	Pli, Mio	Ss	Por	<i>z</i>			
14	Mio, Frio, Vicksburg	Mio, Olig	SH	Por	32 <i>z</i>			
15	{ Pli, Mio, Mid-Olig, Frio, Vicksburg	{ Pli, Mio, Olig	{ SH Ss	Por	40 <i>z</i>	D	264	McElroy
16	{ Cap rock, Pli, Mio, Mid-Olig	{ Pre-Ter, Pli, Mio, Olig	{ L, SH, Ss	{ Cav Por	46 <i>z</i>	Ds	143	Vicksburg
17	{ Pli, Mio, Mid-Olig, Frio	{ Pli, Mio, Olig	Ss, SH	Por	30 <i>z</i>	D	90	Vicksburg
18	Oakville, Cockfield	Mio, Eoc	SH	Por	10 <i>z</i>	Ds	63 <i>z</i>	Sparta
19	{ Mio, Mid-Olig, Vicksburg	Mio, Olig	SH	Por	43 <i>z</i>	Ds	180	Vicksburg <i>y</i>
20	{ Pli, Mio, Mid-Olig, Frio, Vicksburg	{ Pli, Mio, Olig	Ss	Por	250±	Ds	169	Vicksburg
21					75 <i>z</i>	Ds	144	McElroy
22	Pli, Mio	Pli, Mio	Ss	Por	42 <i>z</i>			
23	Mio, Frio	Mio, Olig	Ss	Por	80 <i>z</i>			
24						Ds	216	Cook Mt.
25	Pli, Mio, Mid-Olig	{ Pli, Mio, Olig	S	Por	60			
26	Yegua	Eoc	SH	Por	150 <i>z</i>			
27	Mio, Mid-Olig, Frio	Mio, Olig	SH	Por	60	Ds	112	Jackson
28	Mio, Frio, Vicksburg	Mio, Olig	Ss	Por	130 <i>z</i>	Ds	170	Hockleyensis
29	Frio	Olig	Ss	Por	15 <i>y</i>	D	8	Cockfield
30	{ Pli, Mio, Mid-Olig, Frio	{ Pli, Mio, Olig	SH	Por	54	Ds	63	Jackson
31	Pli, Mio, Mid-Olig	{ Pli, Mio, Olig	Ss, SH	Por	35 <i>z</i>	Ds	114	Mid-Olig
32	Mio	Mio	S	Por	10	Ds	108	Mid-Olig
33	Pli, Mio	Pli, Mio	S	Por	10	Ds	55	Mio
34	Cap rock, Frio	Pre-Ter, Olig	L, SH	{ Cav Por	30	Ds	64	Caddell
35	Mio	Mio	S	Por	10	ML	6	McElroy
36	Cap rock, Mid-Olig, Frio	Pre-Ter, Olig	L, SH	{ Cav Por	60	Ds	72	Vicksburg
37	{ Mio, Mid-Olig, Jackson, Yegua	{ Mio, Olig, Eoc	{ SH Ss	Por	100 <i>z</i>	Ds	117	U. Saline Bayou
38	Lagarto	Mio	S	Por	20	D	54	Frio
39	Mio, Mid-Olig	Mio, Olig	S, SH	Por	60 <i>y</i>	Ds	40	Vicksburg

TABLE 1.—(Continued)

Line Number	Field, County	Age, Years to End of 1936	Area Proved, Acres				Total Oil Production, Bbl.		
			Oil	Oil and Gas ^a	Gas	Total	To End of 1936	During 1935	During 1936
40	Orchard, Ford Bend.....	11	220	0	50	270	3,097,379	239,016	206,847
41	Allen, Brazoria.....	10	10	0	0	10	81,561	3,242	3,228
42	Fannett, Jefferson.....	10	90	0	0	90	1,915,880	239,534	329,714
43	Clay Creek, Washington.....	9	300	0	0	300	3,650,548	361,641	398,609
44	Raccoon Bend, Austin.....	9	2,812	0	600	3,412	17,056,666	1,681,210	1,941,871
45	Shallow.....	9	1,458			1,458	15,348,938	1,082,040	969,755
46	Deep.....	3	1,354			1,354	1,707,728	599,170	972,116
47	Refugio, Refugio.....	9	1,877	0	2,720	4,597	33,612,119	1,437,200	1,788,649
48	Shallow.....		1,025			1,025	21,286,435	650,000 ¹	780,000 ¹
49	Deep.....		852			852	12,325,684	787,200 ¹	1,008,649 ¹
50	Rockland, Jasper.....	9	20	0	0	20	30,858	797 ^y	791
51	Sugarland, Fort Bend.....	9	1,165	0	0	1,165	24,867,251	2,098,407	1,732,343
52	Esperson, Liberty.....	8	400	0	0	400	4,186,658	439,300	632,771
53	Hankamer, Liberty.....	8	420	0	0	420	4,308,239	553,909	779,294
54	Lost Lake, Chambers.....	8	55	0	0	55	842,302	85,737	66,796
55	Port Neches, Orange.....	8	175	0	0	175	4,037,199	596,196	561,260
56	Agua Dulce, Nueces.....	7	0	500	9,500	10,000	241,230	72,894	39,422
57	Shallow.....								
58	Deep.....								
59	Danbury, Brazoria.....	7	0	40	0	40	4,599	0	50±
60	Moss Bluff, Chambers and Liberty	7	10	0	0	10	179,235	(Prod. Depleted 1933)	
61	Mykawa, Harris.....	7	270	0	0	270	2,321,088	710,024	1,176,864
62	Pettus District, Bee								
62	Pettus.....	7	600	0	100	700	8,070,182	504,856	520,961
63	Kimball.....	7	25	0	0	25	(Prod. included with Pettus)		
64	Hartzendorf.....	2	20	0	0	20	(Prod. included with Pettus)		
65	Normanna.....	7	20	0	0	20	49,828	2,856	3,914
66	North Pettus, Bee, Goliad and Karnes.....	7	560	20	20	600	1,841,570	446,262	556,728
67	Tuleta, Bee.....	5	80	25	0	105	(Prod. included with West Tuleta)		
68	West Tuleta, Bee.....	3	800	0	0	800	1,310,477	717,560	349,956
69	Caesar, Bee.....	3	285	0	175	460	598,741	272,712	319,159
70	Dirks, Bee.....	3	865	0	0	865	2,359,324	643,443	1,710,812
71	Holzmark (Foley), Bee.....	2	60	0	20	80	3,994	335	3,659
72	Ray, Bee.....	2	400	0	0	400	913,635	298,052	615,583
73	Worth, Bee.....	2	50	0	0	50	21,194	9,691	11,503
74	Plummer, Bee.....	1	40	0	0	40	730		730
75	Voss, Bee.....	1	100	0	0	100	36,587		36,587
76	Saxet, Nueces.....	7	4,286	0	1,300	5,586	8,183,946	1,049,000	4,864,619
77	White Point, San Patricio.....	7	0	20	3,865	3,885	78,901	11,908	5,861
78	Slick, Goliad.....	6	25	0	0	25	53,928	0 ^y	526
79	Lucas, Live Oak.....	6	0	500	4,000	4,500	169,027	63,470	22,593
80	Manvel, Brazoria.....	6	1,741	0	0	1,741	7,386,253	2,485,585	3,030,625
81	Shallow.....		748			748	^y	^y	^y
82	Deep.....		993			993	^y	^y	^y
83	McFaddin, Victoria.....	6	0	10	845	855	69,008	37,895	3,785

TABLE 1.—(Continued)

Line Number	Total Oil Production, Bbl.	Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells								Depth, Average in Feet
	Daily Average during Nov. 1936	To End of 1936	During 1935	During 1936	Maximum Daily during 1936	Completed to End of 1936	During 1936		At End of 1936					Bottoms of Productive Wells
							Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas ^a	Producing Gas Only	Total Producing	
40	497					28	3	13	1	14			14	{ 1,300 6,700
41	10					5	0	0	0	1			1	5,030
42	809					20	6	1	0	19			19	{ 4,000 5,700
43	1,003					65	11	0	0	51		4	55	1,250
44	4,959		516			219	35	0	17	169		5	174	3,450
45	2,468					139	3		17	91		4	95	4,100
46	2,491					80	32		0	78		1	79	{ 2,700 ^a 4,900
47	5,092					421 _y	25 _y	_y	8 _y	103		62	165	{ 3,700 5,400
48	2,215 ¹													1,275
49	2,877 ¹													
50	0					8	0	8	_y				0	3,600
51	2,597					71	1	0	10 _y	52			52	{ 2,300 4,100
52	1,718					49	17	7	1	40		2	42	{ 2,700 5,700
53	1,745					40	7	5	_y	35			35	2,735
54	158					13	1	0	2	8		1	9	3,942
55	1,029					19	0	0	0	18			18	2,005 ⁴
56	_y					_y	_y	_y	_y	0	_y	19	19 _y	4,820 ⁴
57														5,781
58														{ 830 ³ 5,800
59	0					2	1	0	1	0			0	4,593
60						5								3,900
61	2,403					41	7	4	_y	29		1	30	3,650
62	1,395					88	4	10	_y	39		4	43	3,651
63						3	0	1	_y					3,630
64						1 _y	_y	_y	_y					3,664
65	10					3	0	1	0	2			2	4,138
66	1,570					77	43	0	7	67		9	76	3,960
67						12	0	0	2 _y		2	_y	2 _y	3,055
68	854					73	3	12	7	36		7	43	3,875
69	615					42	6	4	_y	36		2	38	{ 4,064 4,075
70	3,411					100	29	1	0	99			99	3,944
71	35					5	4	0	_y	3	1 _y	1	5 _y	3,407
72	1,264					43	8	3	_y	40			40	3,042
73	24					2	0	0	0	2			2	4,005
74	4					3	3	0	2	1			1	{ 2,360 ⁴ 4,090
75	313					7	7	0	0	6		1	7	{ 6,760 2,375 ⁴
76	19,595					371	256	_y	16 _y	326	_y	29	355 _y	{ 4,902 4,225
77	25					35	0	0	0	1		15	16	{ 2,090 ⁴ 3,533
78	0					3	0	0	3				9	5,287
79	78					39	3	0	8	3	7	17	27	4,016
80	7,265					140	39	0	3	133		4	137	5,160
81	_y					_y	_y		_y	68		_y	_y	{ 2,470 ⁴ 6,187
82	_y					_y	_y		_y	65		_y	_y	
83	3	1,071 _y	163	154 _y		4	0	0	_y	1		2	3	

^a Gas.

TABLE 1.—(Continued)

Line Number	Depth, Average in Feet	Oil Production Methods at End of 1936					Pressure, Lb. per Sq. In. ^d		Character of Oil, Approx. Average during 1936					Character of Gas, Approx. Average during 1936			
		Number of Wells				Injection into Reservoir ^e	Initial	Average at End of		Gravity A.P.I. at 60° F.				Sulphur, Per Cent	Base ^e	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.
		Flowing	Pumping	Gas-lift	Air-lift			1935	1936	Maximum	Minimum	Weighted Average					
40		5	9				375			54	22	35	y	A			
41			1				200			41.3	23.3	34.3	0.11	A			
42		2	17				540			30	25	28	y	A			
43		8	43				350			27	23	26	0.36	A			
44		70	99							38	16	30	0.18	A			
45	3,430	3	88				275	250 ^a		32	16	28			1,000	0.80	
46	3,975	67	11				e1,800	550 ^a		38	32	34					
47		63	40				1,200			60	21	31	0.14	A			
48	3,600						550					33	0.10				
49	1,260 ^y						1,700					29	0.17				
50										25	21	21	0.26	A			
51	3,450	43			9	y	e1,570	e1,372	e1,376			28	0.31	A			
52		11	29				100			26	22	24	0.26	A			
53		9	26				424			26	15.7	23.4	0.33	A			
54	2,679		8				490			23.8	18	22.4	0.22	A			
55		4	14				155	1,700		38	19.4	29	0.26	A			
56										59		59	0.02	M			
57	1,998						865	800	700 ^y	Distillate					A		
58	4,804						1,900	1,650	1,500 ^y						A		
59	5,761								2,200						A		
60	800						280					29.7	0.21	A			
61		6	23				290			30.5	27	28.2	0.14	A			
62	3,860		39				236			49	45	47	0.05	M			
63							100					45.1	y	M			
64	3,642											45	y	M			
65	3,613		2				150					40	y	M			
66	3,655	36	31							51	45	47	y	M			
67	4,102	1		1			534			51	45	46	y	M			
68	3,935	14	17	5			792			51	45	47	y	M			
69	3,040	2	28	6			{ 1,160 ^a					26.4	y	M			
70	3,859	85	14				315	850	700			45	y	M			
71		4					1,000										
							1,050										
72	3,838	25	15				450	450	400			46	y	M		0.80	
73		1	1				850					30.3	y	M			
74		1					1,010		1,000								
75	4,000	6										45	y	M			
76	{ 2,340 4,080 6,720	291	35				{ 1,325 ^a 745	{ 1,200 600		50	20	31	0.18	M			
77	4,880	1					{ 764 ^a 2,000					31	0.09	M			
78	4,211						550	800				48.6	0.04	M			
79	{ 2,020 3,500 5,200	7		3			{ 874 ^a 1,400	{ 375 1,000		42	24	36		A			
80		88	44	1						28	22.8	25	y	A			
81	3,990	25	43	1			1,500	e1,700				24					
82	5,000	63	1	0			2,200	e2,400				26					
83	{ 2,440 6,176	1					{ 1,185 ^a 1,725	{ 1,050 1,220				46	0.16	A	990	0.69	

^a Flowing pressure through tubing on small choke.

TABLE 1.—(Continued)

Line Number	Producing Rock						Number of Dry and/or Near-dry Holes to End of 1936	Deepest Zone Tested to End of 1936	
	Name	Age ^f	Character ^e	Porosity ^a	Net Thickness, Average in Feet	Structure ^d		Name	Depth of Hole, Ft.
40	Mio, Frio, Cockfield	{ Mio, Olig, Eoc	Ss	20y	30	Ds	23	Cockfield	7,892
41	Mio	Mio	SH	Por	10	Ds	30y	Miocene	5,958
42	Mio, Mid-Olig, Frio	Mio, Olig	Ss	20	20	Ds	35	Vicksburg	6,661
43	Claiborne, Wilcox	Eoc	SH	Por	120	Ds	52	Wilcox	7,500±
44						Df	66	L. Saline Bayou	7,061
45	Whitsett, McElroy	Eoc	Ss	25±	40				
46	Cockfield	Eoc	Ss	25±	20				
47			SH	Por	30	D	106y	Vicksburg	9,131
48	Mio	Mio	SH	Por	30				
49	Frio	Olig	SH	Por	30				
50	Cockfield	Eoc	Ss	Por	10	MF	11	Cockfield	1,320
51	{ Heterostegina, Marginulina, Frio	Olig	Ss	25±	80	Ds	5	Vicksburg	4,514
52	Mio, Heterostegina	Mio, Olig	Ss	24	15	Ds	27	{ Weches, Crockett	8,926 9,375 ⁶
53	Mio, Frio	Mio, Olig	Ss	20	29	Ds	16	Dibol (Jackson)	7,681
54	Frio	Olig	Ss	Por	33	Ds	17	Frio	7,471 ⁶
55	Pli, Mio, Frio	{ Pli, Mio, Olig	SH, S	Por	40	Ds	9	Vicksburg	7,667 ⁶
56			SH	30		F	3y	Frio	6,012
57	Fleming	Mio	SH		10				
58	Frio	Olig	SH		16				
59	Marginulina, Frio	Olig	SH	Por	20	Ds	13	Oligocene	7,495
60	{ Cap rock, Marginulina	{ Pre-Ter, Olig	SH	{ Cav Por	33	Ds	61	Vicksburg	7,375
61	{ Mio, Frio, Heterostegina	Mio, Olig	SH	Por	32	D	15	Whitsett	7,355
62	Cockfield (Pettus)	Eoc	Ss	Por	19	DF	22	Queen City	7,569
63	Cockfield (Pettus)	Eoc	Ss	Por	7	D		Yegua	4,503
64	Cockfield (Pettus)	Eoc	SH	Por	9	A		Cockfield	3,651
65	Hockleyensis	Eoc	SH	Por	17	D	2	Yegua	4,596
66	Cockfield (Pettus)	Eoc	Ss	Por	15	DF	11	Yegua	4,660
67	Cockfield (Pettus)	Eoc	SH	Por	13	DF	5	Mt. Selman	6,062
68	Pettus, Hockleyensis	Eoc	SH	Por	10	DF	18	Mt. Selman	6,062
69	Cockfield (Pettus)	Eoc	Ss	Por	15	DF	15	Yegua	3,678
70	Cockfield (Pettus)	Eoc	Ss	Por	16	DF	11	Yegua	4,776
71	Cockfield (Pettus)	Eoc	Ss	Por		NF	7	Yegua	4,458
72	Cockfield (Pettus)	Eoc	SH	Por	15	DF	7	Yegua	4,250
73	Cockfield (Pettus)	Eoc	SH	Por	5	D	11	Yegua	3,600
74	Cockfield (Pettus)	Eoc	Ss	Por	y	NF	2	Cook Mt.	4,256
75	Cockfield (Pettus)	Eoc	Ss	Por	5y	NF	5	Upper Yegua	4,308
76	{ Oakville ⁴ , Mid-Olig, Frio	Mio, Olig	Ss	Por	{ 10 ⁴ 18	DF	49	Frio	7,060
77	{ Lagarto, Mid-Olig	Olig	Ss	Por	10	D	27y	Frio	7,211
78	Cockfield	Eoc	Ss	Por	10	D	4	U. Saline Bayou	4,574
79	{ Catahoula ⁴ , Frio, Yegua	{ Mio, Olig, Eoc	S SH	Por	28	D	22	Cook Mt.	6,789
80					24	D	35	Vicksburg	7,957
81	Mio	Mio	SH	Por	23				
82	Marginulina	Olig	Ss	Por	26				
83	{ Catahoula ⁴ , Frio	{ Mio, Olig	S S	Por	{ 20 ⁴ 10	AF	9	Vicksburg	7,023

^a In salt.

TABLE 1.—(Continued)

Line Number	Field, County	Age, Years to End of 1936	Area Proved, Acres				Total Oil Production, Bbl.		
			Oil	Oil and Gas	Gas	Total	To End of 1936	During 1935	During 1936
84	Thompsons, Fort Bend.....	6	3,185	700	0	3,885	21,725,965	4,094,375	3,522,892
85	Arriola, Hardin.....	5	100	0	0	100	1,464,413	410,000	390,981
86	Buckeye, Matagorda.....	5	50	0	0	50	594,746	71,787	71,111
87	Conroe, Montgomery.....	5	19,000	0	0	19,000	71,857,367	15,575,606	14,905,462
88	Keeran, Victoria.....	5	200	0	0	200	465,207	108,890	112,486
89	O'Conner, Victoria and Refugio	5	200	0	200+	400	340,880	112,846	93,201
90	Pledger, Brazoria.....	5	20	0	1,100	1,120	17,068	62	0
91	Garwood, Colorado.....	4	10	0	0	10	2,024	(Prod. depleted 1933)	
92	Greta, Refugio.....	4	5,414	0	1,050	6,464	15,220,564	4,708,780	5,381,404
93	Livingston, Polk.....	4	0	1,698	0	1,698	3,287,564	1,037,388	1,107,898
94	Premont, Jim Wells.....	4	0	200	0	200	8,603	3,963	800
95	Tomball, Harris.....	4	7,350	0	1,200	8,550	5,759,335	1,910,336	2,626,409
96	Ace, Polk.....	3	0	90	0	90	63,155	16,135	34,370
97	Angelita, San Patricio.....	3	40	0	0	40	30,586	7,718	86y
98	Brookshire, Waller.....	3	50	0	0	50	13,498	8,002	2,856
99	Cleveland, Liberty.....	3	400	0	0	400	717,499	242,803	303,356
100	Coletto Creek, Victoria.....	3	0	350	350	700	489,807	203,519	269,336
101	Dickinson, Galveston.....	3	0	4,300	0	4,300	1,243,986	289,912	947,171
102	Eureka, Harris.....	3	0	50	0	50	11,311	4,451	5,500
103	Hastings, Brazoria.....	3	2,800	0	0	2,800	3,053,745	623,815	2,429,930
104	Kittrell, Houston.....	3	150	0	0	150	771,347	382,001	354,019
105	Louise, Wharton.....	3	1,570	0	0	1,570	1,132,417	412,733	531,836
106	McNeil, Live Oak.....	3	100	0	0	100	157,402	99,993	43,920
107	Old Ocean, Brazoria.....	3	100	0	0	100	280,710	103,370	159,772
108	Port Lavaca, Calhoun.....	3	200	0	30	230	280,211	141,306	133,875
109	Samfordyce, Hidalgo.....	3	1,200	0	0	1,200	3,179,080	1,237,494	1,775,972
110	Sinton, San Patricio.....	3	225	100	0	325	65,637	49,734	11,507
111	Splendora, Montgomery.....	3	0	100	0	100	996	320	(Abnd. for oil 1935)
112	Tomoconnor, Refugio.....	3	4,400	0	0	4,400	1,993,691	522,212	1,432,159
113	Vanderbilt, Jackson.....	3	20	0	50	70	114,829	22,694	26,809
114	Van Vleck, Matagorda.....	3	500	0	0	500	423,698	28,533	382,812
115	Anahuac, Chambers.....	2	5,650	0	0	5,650	2,965,319	362,039	2,603,280
116	Baldwin, Nueces.....	2	270	0	0	270	311,528	77,119	234,409
117	Dinero, Live Oak.....	2	0	50	20	70	49,162	28,376	20,786
118	Driscoll, Clara, Nueces.....	2	500	0	0	500	89,151	4,829	84,322
119	Edinburg, Hidalgo.....	2	0	100	0	100	500	500y	
120	Fort Merrill, Live Oak.....	2	50	0	0	50	25,128	10,031	15,097
121	Hardin-Kenefick, Liberty.....	2	100	0	0	100	190,103	55,325	134,778
122	Hords Creek, Goliad.....	2	100	0	50	150	20,931	4,165	16,766
123	Mauritz, Jackson.....	2	50	50	0	100	62,437	14,045	48,392
124	Mercedes, Hidalgo.....	2	50	0	0	50	76,897	34,182	42,715
125	Pickett Ridge, Wharton.....	2	320	0	1,000	1,320	724,890	49,056	675,834
126	Placedo, Victoria.....	2	3,400	0	50	3,450	1,498,175	151,175	1,347,000
127	Plymouth, San Patricio.....	2	1,970	0	0	1,970	4,088,243	658,761	3,429,482
128	Saxet Heights, Nueces.....	2	1,500	0	0	1,500	2,233,293	9,335	2,223,958
129	South Houston, Harris.....	2	500	0	0	500	1,307,265	80,415	1,226,850
130	Taft, San Patricio.....	2	350	0	0	350	371,243	2,000y	369,243
131	Turtle Bay, Chambers.....	2	200	0	0	200	157,851	2,858	154,993
132	Alta Mesa, Brooks.....	1	125	0	50	175	6,115		6,115
133	Alta Verde, Brooks.....	1	40	0	0	40	y		y

TABLE 1.—(Continued)

Line Number	Total Oil Production, Bbl.	Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							Depth, Average in Feet
	Daily Average during Nov. 1936	To End of 1936	During 1935	During 1936	Maximum Daily during 1936	Completed to End of 1936	During 1936		At End of 1936				
							Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas ^b	Producing Gas Only	Total Producing
84	7,532					208	5	y	y	204		204	5,290
85	751					15	2	0	0	13		13	4,400
86	146					2	0	0	0	2		2	7,926
87	34,203	59,923 _y	x	10,934 _y		946	44	1 _y	6 _y	936		939	5,150
88	297					8	2	0	0	4		5	5,860
89	245					11	0	1	0	4		8	3,100
90	0					10	0	0	0			10	6,800
91						2							5,132
92	12,746					220	9	0	y	205		14	2,100 ^a
93	2,913					97	18	4 _y	0	88		1	3,500
94	0					5	1	y	1	1		3	5,900
95	7,204	y	y	2,853 _y		303	72	0	1	248		54	4,276
96	147					3	1	1	0	2		2	5,555 ^a
97	0					2	0	0	1	1		1	5,575
98	9					1	0	0	0	1		1	4,877
99	611					17	6	1	6	7		1	5,380
100	644					28	7	4	y	20		4	2,974
101	2,546					64	45	0	5	53		6	5,900
102	0					2	1	0	0			1	4,276
103	6,285					123	77	0	0	122	1	1	5,380
104	780					14	1	0	1	13		13	2,055
105	1,433			1,280	3.5	39	17	1	3	34		34	5,157
106	108					9	0	y	4 _y	5		5	6,467
107	564					3	1	0	0	3		3	4,434
108	365			1,080	3	13	0	0	0	10		3	4,992
109	3,912					181 _y	58 _y	y	y	171	y	9	8,654
110	31					7 _y	0 _y	y	2 _y	4		180 _y	9,963
111	(Abnd. for oil 1935)					1	0	0	1			0	6,251
112	5,179					85	57	0	0	85		85	2,790
113	83					2	0	0	0	1		1	5,530
114	1,601					19	15	0	0	19		19	5,840
115	7,442					145	109	0	1	143		143	5,930
116	454					9	2	0	0	8		1	5,582
117	35					4	0	0	1	2		1	7,075
118	385					7	6	0	0	7		7	7,090
119	0					1 _y	0 _y	0	1			0	3,877
120	9					2	0	0	0	2		2	4,069
121	385					1	0	0	0	1		1	5,220
122	28					5	2	0	1 _y	2		1	3,816
123	101					1	0	0	0	1		1	6,770
124	105					4	1	0	0	4		4	4,643
125	1,676					35	31	0	1	33		1	7,690
126	5,305					104	83	0	1 _y	95		8	4,584
127	10,466					114	70	0	1	113		113	5,650
128	8,495					205	201	0	0	205		205	4,096
129	4,102					74	65	0	0	73		1	4,050
130	1,929					32	31	0	0	32		32	4,800
131	636					7	6	0	0	7		7	4,938
132	82					4 _y	2	0	2 _y	2		2	6,620
133						5 _y	5 _y	0 _y	5 _y	0 _y		0 _y	1,140 ^a
													2,475
													926

TABLE 1.—(Continued)

Line Number	Depth, Average in Feet	Oil Production Methods at End of 1936					Pressure, Lb. per Sq. In. ^d		Character of Oil, Approx. Average during 1936					Character of Gas, Approx. Average during 1936	
		Number of Wells				Injection into Reservoir ^c	Average at End of		Gravity A.P.I. at 60° F.					B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.
		Flowing	Pumping	Gas-lift	Air-lift		Initial	1935	1936	Maximum	Minimum	Weighted Average	Sulphur, Per Cent.	Base ^e	
84	5,100	187	17				e2,430	e2,345	e2,340			25	0.20	A	
85	2,990	1	12				440	400		42	27	34	0.13	A	
86	7,831		2				1,045					38	0.07	A	
87	5,000	904	20	12			e2,275	e2,083	e2,076			38	0.05	M	1,132
88	5,850	3	1				{ 2,400 ^a 1,450			48	28	37	y	A	
89	3,075	1		3			365 ^a	110	50			35	0.16	A	1,000
90	6,650						2,450	2,450	2,450			55.8	y	M	
91							1,225					44	x	M	
92	{ 2,000 3,470 5,900	190		15			1,350	900	875	39	23	24	0.20	A	
93	4,241	73	8	7			700					40.7	0.05	M	
94	3,248	1										22.8	y	A	
95	{ 5,375 5,555	237		11			e2,490	e2,050	y	45.4	37.5	41	0.04	M	0.80
96	4,855	2					1,400			50.7	40.4	48	y	M	
97	5,370	1					1,140					33.7	0.13	A	
98	2,955	1					100					24	y	A	
99	5,700	7					1,350	1,000	1,000	45	38	40	y	A	
100		19	1					500y		32.5	20	25	y	A	
101	{ 7,980 9,080	53					1,250 ^a	1,250 ^a		54	35	37.5	0.07	M	
102	7,662	1					2,950	2,850	2,810			54.6	y	M	
103	5,600	122					2,175	2,175	2,175	32	30	31	y	M	
104	1,975	1	12				360	200				24	0.19	A	
105	{ 5,128 6,457	27	5	2			730	660	481	42.1	20.2	26.3	y	A	
106		5					1,150	1,400				44.3	y	Ay	
107	8,632	3					1,650					67y	y	M	
108		8		2			500	1,200	850	61	41	43	y	M	1,000
109	2,770	166					1,000	900				21.5	y	y	
110	5,520	2	2				2,200			49	36.5	47	y	A	
111	5,835						2,000					65	y	A	
112	5,850	85					1,040	1,000	880			36	0.02	A	1,000
113	5,562	1					500					32	0.13	A	
114	7,020	19					1,700			56	40	48	y	M	
115	7,000	143					e3,260	e3,260	e3,190	35.1	34.7	34.9	0.00	M	
116			8				225	225				25.8	y	M	
117	5,200	1	1				1,600	1,350				44.2	y	A	
118	3,807	7					750	750				23.8	y	M	
119	6,685											7			
120	4,637	1	1				1,100	1,100				46	y	Ay	
121	7,665	1					900	900				36.3	y	Ay	
122		2					1,550	1,500				47.6	y	Ay	
123	5,634	1					900		650			30.7	0.10	A	
124		4					2,500	2,500				56.9	y	y	
125	4,690	30	3				900	900				25.2	y	A	
126		84	10	1			{ 825 1,900 2,200	{ 825 1,900 2,200				{ 22.8 36.4 32	y	A	
127		113					{ 1,100 1,650	{ 1,100 1,650	{ 2,000 1,000			{ 31 23.3	y	A	
128		193	12				{ 1,300 1,600	{ 1,300 1,600				{ 32 25	y	M	0.50
129	{ 3,875 4,575	60	13				{ 1,600 600	{ 1,600 600	32	18		22.4	y	A	
130	3,950	32					2,400	2,400	2,400	32.6	30.6	32	y	M	
131	6,600	7										25	0.00	P	
132	{ 1,100 2,450	2					{ 500 ^a 100	{ 500 100		25.2	24.8	25	y	P	
133	916						100		0y			26.2	y	P	

⁷ Distillate.

TABLE 1.—(Continued)

Line Number	Producing Rock						Number of Dry and/ or Near-dry Holes to End of 1936	Deepest Zone Tested to End of 1936	
	Name	Age ¹	Character ²	Porosity ³	Net Thickness, Average in Feet	Structure ⁴		Name	Depth of Hole, Ft.
84	Mid-Olig. Frio	Olig	Ss	25	84	D	28	Vicksburg	8,339
85	Mio. Frio	Mio, Olig	Ss	Por	50±	Ds	10	Yegua	8,743
86	Frio	Olig	SH	Por	60	D	4y	Frio	9,457
87	{ U. Cockfield, { Conroe	Eoc	Ss	27z	{ 14 { 56	D	48	L. Saline Bayou	8,011
88	Frio	Olig	S	15	10	MF	6	Vicksburg	7,715
89	Mio, Catahoula	Mio, Olig	SH	Por	20	DF	12	Oligocene	5,748
90	Frio	Olig	S	Por	100	D	6	Frio	8,115
91	Yegua	Eoc	S	Por	12	D	10	Cook Mt.	8,766
92	{ Catahoula, { Heterostegina, Frio	{ Mio, { Olig	Ss	{ 20 { 33	{ 204 { 18	A	14y	Frio	6,725
93	Cockfield	Eoc	SH	25z	10	DF	32	Yegua	5,596
94	Olig	Olig	S	Por	10	D	5y	McElroy	7,135
95	Cockfield, Yegua	Eoc	Ss	25z	9	DF	29	Yegua	7,438
96	Cockfield	Eoc	Ss	25z	9	NF	11	Yegua	5,533
97	Frio	Olig	Ss	Por	14	Nf	Frio	7,131	
98	Frio	Olig	Ss	Por	16	D	10y	Hockleyensis	7,215
99	Cockfield, Yegua	Eoc	Ss	15	8	MF	6	Cook Mt.	8,734
100	Catahoula, Frio	Mio, Olig	Ss	Por	10	MF	16	Frio	5,368
101	Frio	Olig	Ss	Por	12	DF	10	Frio	9,360
102	Frio z	Olig	SH	Por	21	D	3	Frio	8,070
103	Frio	Olig	Ss	Por	60	D	3	Vicksburg	8,792
104	Carrizo, Wilcox	Eoc	Ss	Por	17	Ds	15	Wilcox	5,501
105	Frio	Olig	Ss	Por	29	D	8	Vicksburg	8,271
106	{ Hockleyensis, { Cockfield	Eoc	S	Por	10	D	4y	Cook Mt.	6,210
107	Frio	Olig	S	Por	22	D	6	Frio	9,963
108	Marginulina	Olig	S	Por	15	DF	11	Frio	6,780
109	Frio	Olig	S	Por	20	A	30y	Vicksburg	5,395
110	Frio	Olig	Ss	Por	10	D	2y	Frio	7,245
111	Cockfield	Eoc	Ss	Por	5	D	9	Cockfield	6,452
112	Frio	Olig	Ss	Por	45	Af	0y	Frio	8,174
113	Frio	Olig	SH	Por	8	DF	5	Frio	7,042
114	Marginulina, Frio	Olig	SH	Por	21	D	2	Frio	8,708
115	Frio	Olig	Ss	Por	60	DF	11	Frio	8,749
116	Mio	Mio	S	Por	12	AF	6y	Frio	6,610
117	Yegua	Eoc	S	Por	7y	D	4	Cook Mt.	5,913
118	Catahoula	Mio	S	Por	10	DF	2y	Frio	6,136
119	Frio	Olig	SH	Por	20y	D	0y	Frio	7,508
120	Yegua	Eoc	S	Por	5	D	0	Crockett	5,425
121	Yegua	Eoc	S	Por	20	D	3	Yegua	8,110
122	Yegua	Eoc	SH	Por	10	MF	7	Cook Mt.	6,004
123	Frio	Olig	Ss	Por	16	D	5	Vicksburg	7,408
124	Frio	Olig	SH	Por	10	D	3	Frio	8,044
125	Marginulina	Olig	S	Por	16	A	7	Vicksburg	6,546
126	{ Heterostegina, { Frio	Olig	SH	Por	12	Af	7y	Frio	6,468
127	Frio	Olig	Ss	Por	20	MC	13	Frio	7,035
128	Catahoula	Mio	S	Por	10z	A	5y	Frio	7,020
129	{ Mio, { Frio	{ Mio, { Olig	Ss	Por	{ 20 { 40	Ds	11	Hockleyensis	6,050
130	Heterostegina	Olig	Ss, SH	Por	20	D	2	Frio	6,352
131	Marginulina	Olig	Ss	Por	10	D	2	Frio	8,025
132	Mio	Mio	Ss	Por	20	D	10	Vicksburg	8,022
133	Mio	Mio	S	Por	10	Ds	10	Yegua	5,096

8698 ft. into the Vicksburg and then was plugged back to 6257 ft., where it made gas.

Heyser.—Humble Oil & Refining Company's Welder No. 2 was the discovery well of this field. It was brought in May 15 for 126 bbl., 800 lb. on the casing and 90 lb. on the tubing. The completion depth was 5475 ft. after being plugged back from 6050 feet.

Chambers County.—The Anahuac field was extended by Humble Oil & Refining Co. when the company drilled Boyt No. 1 in sec. 44, H. T. & C. survey. A potential test on Aug. 9 showed 706 bbl. on a $\frac{1}{4}$ -in. choke with 1050 lb. on the tubing.

Cotton Lake.—The presence of the Cotton Lake field was indicated by the Gem Oil and Salt Dome Companys' Lawrence No. 2, after being plugged back to 6661 ft. from a total depth of 7303 ft. The well made salt water and a small amount of oil and was abandoned. Glenn McCarthy's Kilgore No. 1, the first consistent producer, came in Aug. 9 for 207 bbl. on a $\frac{1}{8}$ -in. choke.

Seabreeze.—Sun Oil Company's Acom No. 1, in this area, came in as a gas well making a small amount of distillate at a plug-back depth of 8190 ft. from a total depth of 8335 feet.

TABLE 1.—(Continued)

Line Number	Field, County	Age, Years to End of 1936	Area Proved, Acres				Total Oil Production, Bbl.		
			Oil	Oil and Gas ^a	Gas	Total	To End of 1936	During 1935	During 1936
134	Amelia, Jefferson.....	1	2,000	0	0	2,000	204,195		204,195
135	Aransas, Aransas and San Patricio	1	250	0	0	250	36,688		36,688
136	Bentonville, Jim Wells.....	1	0	120	0	120	113,223		113,223
137	Clinton, Harris.....	1	0	20	0	20	2,996		2,996
138	Cotton Lake, Chambers.....	1	200	0	0	200	43,029		43,029
139	Fairbanks (Satsuma), Harris.....	1	80	0	0	80	28,259		28,259
140	Five Corners, Wharton.....	1	100	0	600	700	1,746		1,746
141	Flour Bluff, Nueces.....	1	2,500	0	0	2,500	94,357		94,357
142	Greens Lake, Galveston.....	1	100	0	0	100	19,332		19,332
143	Hawkinsville, Matagorda.....	1	50	0	0	50	3,345		3,345
144	Heyser, Calhoun.....	1	3,100	0	0	3,100	138,992		138,992
145	Hitchcock, Galveston.....	1	0	0	40	40			
146	La Sal Viejo, Willacy.....	1	40	0	0	40	13,345		13,345
147	Lockridge, Brazoria.....	1	700	0	0	700	4,310		4,310
148	Magnet, Wharton.....	1	0	40	0	40	2,510		2,510
149	Nome, Jefferson.....	1	500	500	0	1,000	54,534		54,534
150	Seabreeze, Chambers.....	1	20	0	0	20	863		863 ²
151	Segno (Wing), Polk.....	1	40	0	0	40	2,140		2,140
152	Silsbee, Hardin.....	1	200	0	0	200	6,880		6,880
153	South Bay City, Matagorda.....	1	100	0	0	100	33,201		33,201
154	Sullivan, Nueces.....	1	40	0	0	40	6,002		6,002
155	Weser, Goliad.....	1	50	0	0	50	1,166		1,166
156	Withers, Wharton.....	1	700	0	0	700	229,992		229,992
	Total.....		101,395	9,603	29,365	140,363	1,096,174,921	69,597,811	91,224,844

Galveston County.—Coast Petroleum's Maco Stewart No. 3 well in the W. R. Wilson survey marks an extension to Dickinson. The well came in producing a large amount of gas with some distillate. The Sun Oil Company's Hughes No. 2 well was plugged back from 9636 to 3620 ft., where it made 432 bbl. of oil on a drill-stem test. This well is the discovery well of Green's Lake. Shell Petroleum Company drilled the discovery well of the Hitchcock field and tested five different zones by perforating. This was the deepest well drilled on the Gulf Coast, a total depth of 10,460 ft. The well got out of control and blew wild at the rate of 25 million cubic feet of gas per day at a plug-back depth of 5147 ft. Later it sandied up and was plugged and abandoned in 1937.

Goliad County.—Diamond Half's Weldon Lackey No. 1 was completed Aug. 25, 1936, for 133 bbl. on a $\frac{1}{4}$ -in. choke, as a substantial extension of the North Pettus field. Weser field was discovered by Standard Oil Company of Texas in Landgrebe No. 1, which made 120 bbl. on a $\frac{1}{4}$ -in. choke. The well was completed on Oct. 3 after plugging back from 5052 to 4912 feet.

Silsbee.—Brooks Fee No. 1, drilled by Houston Oil Co. and Republic Production Co., blew out at 6982 ft. in the Yegua. It made an estimated

TABLE 1.—(Continued)

Line Number	Total Oil Production, Bbl.	Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells								Depth, Average in Feet
	Daily Average during Nov. 1936	To End of 1936	During 1936	During 1936	Maximum Daily during 1936	Completed to End of 1936	During 1936		At End of 1936					Bottoms of Productive Wells
							Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas ^a	Producing Gas Only	Total Producing	
134	937					17	17	0	0	16		1	17	6,780
135	284					6	6	0	0	4		2	6	6,554
136	640					13	13	0	1	7		5	12	{ 4,000 ^a 5,370
137	36					1	1	0	0		1		1	8,101
138	334					8	8	1	0	6		1	7	6,310
139	208	493		493	4	3	3	0	0	3			3	6,835
140	12					3	3	0	0			3	3	5,550
141	890					16	16	0	0	16			16	6,690
142	52					2	2	1	0	1			1	3,891
143	18					1	1	0	0	1			1	5,160
144	1,109	150		150	2	18	18	0	0	17		1	18	{ 4,876 5,475
145					3.5	1	1	0	1				0	5,134
146	99	44.5		44.5		1	1	0	0		1		1	7,647
147	78					2	2	0	0	2			2	6,365
148	80					1	1	0	0	1			1	5,562
149	382					8	8	0	0	7		1	8	6,058
150	0					1	1	0	0		1		1	8,190
151	0					1	1	0	0	1			1	5,194
152	0					2	2	0	0	2			2	6,980
153	101					1	1	0	0	1			1	9,370
154	108					1	1	0	0	1			1	5,780
155	0					1	1	0	0	1			1	4,812
156	928					17	17	0	0	16		1	17	5,560
	241,942					15,041	1,864	187	401	6,375	14	338	6,727	

Tomoconnor.—A major extension of this field is indicated by Josey and Bruton's Lambert No. 1-A in the Swisher survey. A potential test showed 528 bbl. on a $\frac{1}{4}$ -in. choke.

Placedo.—Placedo was extended to the southwest by Barnsdall Oil Company's Falmont No. 1, which was completed at 4774 ft. after a plug-back job from 6319 feet.

Wharton County.—The Texas Company's Pierce Estates B-1 opened a new field at Five Corners. Later wells proved oil production in this area. Total depth 6511 ft., plug-back depth 5536 feet. The Magnet area was discovered by Texas Crusader and Cockburn's Cockburn Fee No. 1, which produced 120 bbl. on an $\frac{1}{8}$ -in. choke. Pickett Ridge was

TABLE 2.—*Summary of Drilling Operations in Texas Gulf Coast*

Important Wildcats Drilled in 1936

	County	Location	Total Depth, Ft.	Surface Formation	Deepest Horizon Tested
1	Aransas.....	Sur. J. Oriek Cent. Blk. 41 & 42	7,501	Alluvium	Marginulina
2	Bee.....	S. May Sur. A-230 on E. Holzmark Tract	4,101	Lissie	Pettus
3	Bee.....	S. May Sur. A-230 on R. Voss Tract	4,003	Lissie	Pettus
4	Brooks.....	LaMestena Sur. on J. Garcia Tract	8,022	Quaternary	Vicksburg
5	Brooks.....	S. Alarcon Sur. Blk. 12 Sec. 312	925	Quaternary	Cap rock (Mio)
6	Brazoria.....	A. Robinson Sur. on J. E. Fairfield Tract	8,698	Beaumont	Vicksburg
7	Calhoun.....	J. M. Rios Sur. on J. Welder Tract	6,050	Beaumont	Frio
8	Chambers.....	H. T. & C. Sur. Sec. 44 E. W. Boyt	7,129	Beaumont	Marginulina
9	Chambers.....	S. Borrow Sur. A. B. Lawrence Tract	7,303	Beaumont	Marginulina
10	Chambers.....	J. Townsend Sur. J. Kilgore Farm	6,308	Beaumont	Marginulina
11	Chambers.....	H. T. & B. Sur. Sec. 103 Abst. 154 on H. O. Acom.	8,335	Alluvium	Frio
12	Galveston.....	W. K. Wilson Sur. on M. Stewart Tract	8,543	Beaumont	Frio
13	Galveston.....	W. C. M. Baker Sur. Sec. 26 on J. D. Hughes Tract	9,636	Beaumont	Marginulina
14	Galveston.....	J. Spilman Sur. on M. Stewart Tract	10,480	Beaumont	Frio
15	Goliad.....	J. Gomez Sur. on Weldon & Lackey 60 Ac. Tract	3,703	Lissie	Pettus
16	Goliad.....	Thomas Hancock Sur. on W. H. Landgrebe Tract	5,052	Lissie	Yegua
17	Hardin.....	G. W. Brooks Sur. on G. W. Brooks Fee Tract	6,982	Lissie	Yegua
18	Harris.....	Reels & Trobough Sur. on A. Candelari Tract	8,101	Beaumont	Cockfield
19	Harris.....	W.C.R.R. Sur. Sec. 2 on L. Dopslauf Tract	7,520	Lissie	Cockfield
20	Jefferson.....	C. Williams Sur.	6,903	Beaumont	Frio
21	Jefferson.....	H. Williams Sur.	6,105	Beaumont	Frio
22	Jefferson.....	Pevito Sur. Sec. 34	6,888	Beaumont	Marginulina
23	Jim Wells.....	Section 17 King Farm Lots	6,018	Lissie	Frio
24	Matagorda.....	M. Cummins Sur. F. C. Cobb "B"	7,503	Beaumont	Frio
25	Matagorda.....	T. W. Williams Sur. on J. H. Craig Est. Tract	6,326	Alluvium (Sd.)	Miocene
26	Matagorda.....	E. Hall Sur. Abst. 45 on Cleveland 68 Ac. Tract	9,442	Beaumont	Frio
27	Nueces.....	Flour Bluff & Encinal Farm Tracts Lot 9 Sec. 48	7,504	Beaumont	Marginulina
28	Nueces.....	Villareal Sur. Shely Farm	4,092	Beaumont	Miocene
29	Nueces.....	A. Longario Sur. on Austin 526 Ac. Tract.	5,836	Beaumont	Frio
30	Polk.....	I. G. & N. Sur. A-15 on Wings Est. Tract	5,194	Lissie or Lagarto	Cockfield
31	Refugio.....	J. Swisher Sur. Abst. 398 Sec. No. 7	5,903	Beaumont	Frio
32	Victoria.....	S. A. & M. G. R. R. A-306 Pickering & Roos Farm	6,319	Lissie	Frio
33	Wharton.....	A. H. Pierce Sur. A-642 Pierce "B" Block	6,511	Beaumont	Frio
34	Wharton.....	Smith & McKenzie Sur. Lot 8 Block 84	5,562	Beaumont	Frio
35	Wharton.....	G. C. Gifford Sur. Sec. 4. A-660 on J. F. Kubela	4,839	Beaumont	Frio
36	Wharton.....	L. & G. N. R. R. Sur. A-222 on A. Nilson Lease	4,713	Beaumont	Frio
37	Wharton.....	J. Caldwell Sur. A-10 on Pierce "C" Block	7,244	Beaumont	Frio
38	Willacy.....	Las Mestonas Sur. Share No. 64	7,662	Alluvium	Frio

extended by Texas Crusader's Kubela No. 1. The Texas Company's Pierce Estates C-1 was the discovery well of the Withers field.

La Sal Viejo.—The well drilled by Shell Petroleum Co. on the Yturria Farm, Willacy County, was the discovery well for this field. Very few

TABLE 2.—(Continued)

Important Wildcats Drilled in 1936							
	Drilled by	Initial Production per Day		Choke Fractions of an Inch	Pressure Lb. per Sq. In.		Remarks
		Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
1	Buckingham	101		$\frac{1}{8}$ and $\frac{5}{32}$	2,500	2,200	Disc. ¹ Aransas.
2	Miller-Donzis	45		$\frac{1}{8}$	1,000	850	Disc. Holzmark.
3	Swiger-Devonian	96		$\frac{1}{4}$	1,250	1,050	Disc. Voss.
4	California	189		Jetting			Disc. Alta Mesa.
5	Dick Young	90		Pumping			Disc. Alta Verde.
6	Gulf	Gas	1	$\frac{1}{4}$	2,225	2,225	Disc. Lockridge.
7	Humble O & R Co.	126			800	90	Disc. Heyser.
8	Humble O & R Co.	706		$\frac{1}{4}$		1,050	Ext. ² Anahuac.
9	Gem & Salt Dome	360		$\frac{1}{4}$		550	Disc. Cotton Lake (Salt Water P. and A.).
10	McCarthy	207		$\frac{1}{8}$	1,200	1,700	1st Prod. at Cotton Lake.
11	Sun	48		$\frac{1}{4}$	31	32	Disc. Seabreeze.
12	Coast Pet.	Gas w/Distillate		$1\frac{3}{64}$	1,750	2,750	Ext. Dickinson.
13	Sun	432 (24 hr. D.S.T.)		$\frac{3}{8}$ top and bottom		250-350	Disc. Greens Lake.
14	Shell	12	2.5		2,000	1,950	Disc. Hitchcock.
15	Diamond Half	133		$\frac{1}{4}$	520	250	Ext. N. Pettus.
16	California	120		$\frac{1}{4}$	740	260	Disc. Weser.
17	Houston & Republic	350	40	Blowout before testing			Disc. Silsbee.
18	Stanolind	142	10	$\frac{2}{32}$		2,900	Disc. Clinton.
19	Amerada & Stanolind	106		$1\frac{3}{64}$	2,460	2,375	Disc. Fairbanks.
20	Humble O & R Co.	486		$\frac{1}{4}$	800	625	Disc. Amelia.
21	McCarthy	288		$\frac{1}{4}$	2,400	2,175	Ext. Amelia (W. Beaumont).
22	Shell	574		$\frac{1}{4}$	1,450	950	Disc. Nome.
23	Texon Royalty Co.	193		$1\frac{1}{64}$	950	675	Disc. Bentonville.
24	Skelly	826		$\frac{1}{4}$	1,175	1,325	Ext. Bay City
25	Sun	100				60-200	Disc. Hawkinsville.
26	Hamman	155		$1\frac{3}{64}$	300	800	Disc. So. Bay City (Hamman).
27	Barnsdall	600		$\frac{1}{4}$	520	800	Disc. Flour Bluff.
28	Hawn	240		$\frac{3}{16}$	1,500	675	Ext. Saxet Heights.
29	Texon Royalty	48		$\frac{3}{16}$	1,700	1,575	Disc. Sullivan.
30	Dorrance	258		$1\frac{8}{64}$	900	700	Disc. Segno (Wing).
31	Josey & Bruton	528		$\frac{1}{4}$	525	875	Ext. Tomoconnor.
32	Barnsdall	356		$\frac{3}{16}$	520	250	Disc. Placedo.
33	The Texas Co.	Dry gas	234	$\frac{1}{4}$	2,100	2,050	Disc. Five Corners.
34	Cockburn and Texas Crusaders	120		$\frac{1}{8}$			Disc. Magnet.
35	Texas Crusaders	36		$\frac{1}{8}$	1,900	1,200	Ext. Pickett Ridge.
36	The Texas Co.	263		$\frac{3}{16}$		575	Ext. Pickett Ridge.
37	The Texas Co.	391		$\frac{1}{4}$	1,470	1,700	Disc. Withers.
38	Shell	125	3	$\frac{1}{4}$	2,300	2,125	Disc. La Sal Vieja.

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1936.....	156	54
Number of oil wells completed during 1936.....	1,611	132
Number of gas wells completed during 1936.....	67	14
Number of dry holes completed during 1936.....	380	394

¹ Discovery well of the field.² Well is considered an extension of this field.

wells have been drilled in this area and little information is available of this prospect.

ACKNOWLEDGMENTS

The writers gratefully acknowledge the information given on various fields by the following persons: G. C. Francisco, Jr., Sun Oil Co.; Ira Needham, Jr., Pure Oil Co.; E. L. Rawlins, United Production Co.; L. P. Teas, Humble Oil and Refining Co.; W. C. Thompson, General Crude Oil Purchasing Co.; P. L. Vaudoit, Shell Petroleum Co.; C. A. Warner, Houston Oil Co.; Paul Weaver, Gulf Production Co.; R. A. Weingartner, Stanolind Oil and Gas Co. The Engineers' Office of the Railroad Commission of Texas furnished production figures for the past year. The writers are also indebted to J. C. Miller, of The Texas Company, together with his staff, for valuable assistance, and to T. G. Krandel, of the same company, for assistance in compiling the statistical data and preparation of this report.

Oil and Gas Development and Production in North Texas for the Year 1936

BY H. B. FUQUA* AND B. E. THOMPSON*

(New York Meeting, February, 1937)

FOR a very brief description of the North Texas area and the general geological features with which it is associated, the reader is referred to the summary for 1935¹.

As in previous years, the authors have been unable to undertake the almost impossible task of isolating statistics for the hundreds of productive "spots" which are included within the generally productive areas of the several counties. However, pools that appear to be definitely isolated—as, for example, the Foard County production and the new pool recently developed southeast of Gainesville in Cooke County—are covered separately.

During the year 1936, both routine development in proven or semi-proven areas and exploratory drilling showed a decrease over the year 1935, there having been a total of 1453 wells drilled in the district during 1936, as compared to 1619 in 1935. It is also of interest to note that abandonments exceeded completions in 1936.

DEVELOPMENTS DURING 1936

While a number of local productive spots were found in Wilbarger, Archer and Wichita Counties, and numerous minor local extensions to older producing areas were developed in practically all the producing counties in the district, only two discoveries of sufficient importance to justify special mention were made.

Anderson and Kerr No. 1 Bruhlmeier, about two miles southeast of Gainesville in Cooke County, was completed in April, at a total depth of 2014 ft., for an initial production of 315 bbl. daily from a sand of Pennsylvanian (Canyon) age. Development has been rapid and the field is about drilled up. During November the 100 wells in the field averaged about 40 bbl daily. The structure appears to be a small fold associated with the northeast flank of the main uplift, which extends in a northwest-southeast direction across Cooke and Montague Counties.

Manuscript received at the office of the Institute Feb. 17, 1937.

* Gulf Oil Corporation, Fort Worth, Texas.

¹ H. B. Fuqua and B. E. Thompson: Oil and Gas Development in North Texas for the Year 1934. *Trans. A.I.M.E.* (1935) **114**, 417.

Sand lenticularity undoubtedly plays an important part in the accumulation at this point. The average sand thickness is 15 feet.

Sinclair-Prairie et al. No. 2 Holt, about three miles southeast of the nearest oil production in the Nocona pool of north Montague County, was completed in September for an initial production of about 90 bbl. in a Pennsylvanian sand from 1697 to 1731 ft. The well was located on surface structure, which was reported to have been checked by a seismograph survey. Whether or not this production will ultimately be joined with the Nocona field is a matter for debate; but it is undoubtedly associated with the same regional arch.

Deep prospecting has been very limited in the district. The Sinclair-Prairie et al. No. 1 Holt, Montague County, which was directly responsible for the later discovery of the Holt pool, was started as a deep test, but encountered arkosic material at 3480 ft. and granite at 3570 ft. It was abandoned at 3648 ft. The Sinclair-Prairie et al. No. 2 McCall, in extreme northern Cooke County, near Red River, was abandoned in December, after drilling to a depth of 8331 ft. It encountered pre-Pennsylvanian sediments, believed to be Simpson in age, from 8275 ft. to its total depth.

GENERAL COMMENTS

Acid treatment of wells, which played an important part in the development of the limestone areas of Archer and Wilbarger Counties during

TABLE 1.—*Oil and Gas Production in North Texas in 1936*

Line Number	Field, County	Age, Years to End of 1936	Area Proved, Acres				Total Oil Production, Bbl.	
			Oil	Oil and Gas ^a	Gas	Total	To End of 1936	During 1935
1	Petrolia ^{1,2} , Clay.....	34	800	1,000	4,000	5,800	6,505,305	185,881
2	Worsham, Clay.....	13	100	0	0	100	206,000	abandoned
3	All fields, Wichita.....	25	40,560	0	0	40,560	255,016,139	5,565,922
4	All fields, Wilbarger.....	24	9,260	0	0	9,260	59,026,264	2,977,317
5	All fields, Archer.....	24	22,000	0	0	22,000	104,198,077	6,575,589
6	All fields, Montague.....	14	5,000	500	500	6,000	24,182,480	2,027,893
7	Portwood, Baylor.....	12	600	0	0	600	2,926,329	666,261
8	Miscellaneous, Cooke.....	11	2,700	0	0	2,700	10,283,999	762,069
9	Bruhlmeyer, Cooke.....	1	600	0	0	600	471,863	0
10	Thalia, Foard.....	10	0	100	0	100	249,856	23,301
11	Johnson, Foard.....	4	0	600	400	1,000	764,257	248,049
12	Hardeman ³							
13	Knox ⁴							
14	Total.....		81,620	2,200	4,900	88,720	463,830,269	18,972,282

^a Footnotes to column heads and explanation of symbols are given on page 291.

¹ For Petrolia field, total gas production was: 98,521,466 M. cu. ft. to end of 1936; 266,565 M. cu. ft. during 1935; 315,000 M. cu. ft. during 1936. Gas-production data for other areas not available to authors.

² Includes a few isolated producers with negligible production in other parts of county.

³ Number of dry holes drilled in county as follows: 30 to end of 1936; none during 1936.

⁴ Number of dry holes drilled in county as follows: 14 to end of 1936; none during 1936.

the past few years, has been greatly reduced during 1936. The only known area where it has been continued to any extent is in the Rock Crossing area of Wilbarger County.

Since most of the wells in North Texas are submarginal, the effect of proration on daily production is negligible.

OUTLOOK FOR 1937

In 1936, the production of the district increased about 300,000 bbl. over 1935, or by less than the 471,863 bbl. of new production developed in the Bruhlmeier pool of Cooke County. The greatest loss, over a

TABLE 1.—(Continued)

Line Number	Total Oil Production, Bbl.		Number of Oil and/or Gas Wells						Depth, Average in Feet to Top of Productive Zone	Oil Production Methods at End of 1936	
	During 1936	Daily Average during Nov. 1936	Completed to End of 1936	During 1936		At End of 1936				Number of Wells	
				Completed	Abandoned	Producing Oil Only	Producing Gas Only	Total Producing		Flowing	Pumping
1	184,370	483	625	16	51	425	45±	470	1,500	0	425
2			4						3,500		
3	5,759,230	15,777	11,059	190	416	6,553	x	6,553	1,500	10±	6,543
4	3,056,885	8,369	1,891	49	58	1,308	x	1,308	1,700	0	1,308
5	5,336,080	13,923	6,408	221	366	3,966	0	3,966	1,300	40±	3,926
6	2,010,331	5,457	895	79	12	799	21	820	1,000	0	799
7	1,174,569	2,132	183	25	0	164	0	164	1,400	0	164
8	1,108,457	3,160	606	147	19	540	7	547	1,200	0	540
9	471,863	3,938	103	103	0	103	0	103	2,000	0	103
10	25,860	64	13	1	0	8	4	12	2,000	0	8
11	151,261	336	7	1	0	6	0	6	3,800	6	0
12											
13											
14	19,278,906		21,794	832	922	13,872	77±	13,940		56±	13,816

[illegible]

million barrels, was suffered by Archer County. Routine development in all other areas either maintained or improved the rate of production. Such development may be expected to continue and, supplemented by production from lower horizons and by new discoveries from time to time, should maintain the level of production approximately at that of the past year.

TABLE 2.—*Summary of Drilling Operations in North Texas*

Important Wildcats Drilled in 1936

	County	Location			Total Depth Ft.	Surface Formation
		Fee	Survey	Abst.		
1	Cooke.....	Bruhlmeier	H. Strong	930	2014	Cretaceous
2	Cooke.....	McCall	W. H. White	1134	8331	Cretaceous
3	Montague.....	Holt	Kaufman Co.	Sch. Lds.	3648	Permian
4	Montague.....	Holt	Kaufman Co.	Sch. Lds.	1705	Permian

Important Wildcats Drilled in 1936

	Deepest Horizon Tested	Drilled by	Initial Production per Day		Remarks
			Oil, U. S. Bbl.	Gas, Millions Cu. Ft.	
1	Pen (Canyon)	Anderson and Kerr	315		New pool (Bruhlmeier).
2	Possible Simpson	Sinclair-Prairie et al.			Dry hole.
3	Pre-Cambrian	Sinclair-Prairie et al.	90		Dry hole.
4	Pennsylvanian	Sinclair-Prairie et al.			New pool (Holt.).

	In Proven Fields
Number of wells drilling Dec. 31, 1936.....	66
Number of oil wells completed during 1936.....	830
Number of gas wells completed during 1936.....	2
Number of dry holes completed during 1936.....	621

Oil and Gas in North Central Texas in 1936

By H. W. IMHOLZ*

(New York Meeting, February, 1937)

THIS report covers most of the counties in North Central Texas in which oil is being produced in commercial quantities. The exceptions are McCulloch and Runnels, which were omitted because the production is small and the detailed information necessary for a report is not available to the writer.

Complete information was not available regarding the number of wells drilled in this district during the year.

The writer wishes to thank Mr. T. F. Petty, of the Humble Oil and Refining Co., Wichita Falls, Texas, for information used in compiling Table 2.

Manuscript received at the office of the Institute March 13, 1937.

* Consulting Geologist, Abilene, Texas.

TABLE 1.—Oil and Gas Production in North Central Texas

Line Number	Field	Age, Years to End of 1936	Area Proved, Acres	Total Oil Production, Bbl.			
			Oil	To End of 1936	During 1935	During 1936	Daily Average during Dec. 1936
Brown County							
1	Bull-Alcorn.....	9	100	117,397	6,271	4,159	12
2	Byler.....	10	290	812,219	20,822	18,939	28
3	Byrd's Store.....	16	250	387,208	4,191	7,141	10
4	Childress.....	9	180	732,531	37,643	35,322	86
5	Clark-Buffalo.....	9	460	744,077	16,282	13,027	31
6	Cross-Cut.....	15	2,300	5,876,190	131,504	124,684	363
7	Fry.....	11	940	7,517,929	116,078	113,101	312
8	George.....	9	200	705,555	22,697	25,168	82
9	Smith-Ellis.....	10	450	2,156,814	41,939	46,279	123
10	Stover.....	10	1,500	6,664,140	195,654	179,448	507
11	Other fields.....		5,595	2,325,890	111,480	76,144	209
12	Total Brown County.....		12,265	28,039,950	688,279	643,412	1,763
Callahan County							
13	Baum.....	11	500	828,212	28,790	19,095	55
14	Hatchett.....	9	375	1,203,491	64,623	89,800	221
15	Izenhour.....	13	600	2,027,625	63,570	57,911	150
16	Moutray.....	10	400	2,226,750	136,210	125,134	295
17	Other fields.....		9,515	6,465,066	267,905	294,563	773
18	Total Callahan County.....		11,390	12,751,144	561,098	586,503	1,494
Coleman County							
19	Burkett, Shallow.....	12	850	2,104,529	97,185	87,863	231
20	Burkett, Deep.....	6	200	645,737	34,421	21,462	65
21	Dibrell.....	9	170	321,143	11,777	11,268	30
22	Eastland.....	8	270	1,899,834	56,444	62,184	163
23	Jennings.....	9	135	440,147	13,960	6,762	28
24	Overall.....	10	200	1,145,959	60,765	59,967	166
25	Santa Anna.....	14	150	401,307	12,202	10,348	38
26	Stewardson.....	6	200	367,517	34,388	26,417	69
27	Other fields.....		985	1,631,170	142,965	120,891	287
28	Total Coleman County.....		3,160	8,957,343	464,107	407,162	1,057
Comanche County							
29	Sipe Springs.....	17	800	1,373,576	25,923	21,452	59
Eastland County							
30	Hilburn.....	17	400	1,085,970	7,066	5,322	20
31	Mangum.....	14	300	732,063	75,240	69,659	190
32	Pioneer.....	17	1,400	5,265,847	112,315	90,809	235
33	Ramsour.....	11	250	1,394,176	28,518	29,378	73
34	Other fields.....		27,660	62,566,846	709,527	690,229	2,037
35	Total Eastland County.....		30,010	71,231,428	932,666	1,071,923	2,555
Eastland, Erath and Comanche Counties							
36	Desdemona.....	18	6,175	22,643,764	226,622	186,526	552
Fisher County							
37	Howard.....	2	40	84,052	10,755	73,297	174
38	Stephens (Roynston).....	8	2,880	7,712,238	1,982,552	1,577,863	3,488
39	Total Fisher County.....		2,920	7,796,290	1,993,307	1,651,160	3,662
Jones County							
40	Higgs (Sandy Ridge).....	11	450	131,685	25,228	65,858	203
41	Hawley (King).....	11	600	1,080,549	63,776	894,442	2,629
42	Leuders.....	2	160	212,189	15,658	196,531	417
43	Noodle Creek.....	9	1,030	6,096,392	347,891	256,736	623
44	Sayles.....	4	640	415,817	192,988	171,302	400
45	Guitar.....		160	5,469	0	5,469	121
46	Other fields.....		60	72,274	39,519	6,405	19
47	Total Jones County.....		3,100	8,014,375	685,060	1,596,743	4,412
Haskell County							
48	Moody.....	9	40	92,733	6,654	6,098	13
Jack County							
49	Antelope.....	4	350	313,120	25,825	30,701	102
50	Bryson.....	4	600	4,150,587	258,558	808,904	3,736
51	Buttram.....	4	770	2,346,531	200,588	57,075	159
52	Total Jack County.....		1,720	6,810,238	484,971	896,680	3,997
Palo Pinto County							
53	Dalton.....	15	160	346,685	0	12,233	y
54	Hart.....	16	600	752,818	0	2,149	y

TABLE 1.—(Continued)

Line Number	Average Oil Production, Bbl. per Acre	Number of Oil and/or Gas Wells	Depth, Average in Feet	Character of Oil, Approx. Average during 1936		Producing Rock			
				Gravity A.P.I. at 60° F.		Name	Age ¹	Character ²	Structure ³
				Maximum	Minimum				
	To End of 1936	At End of 1936	Bottoms of Productive Wells						
1	1,174	13	1,150	40	37	Fry sand	Pen	S	ML, N
2	2,801	28	1,300	40	38	Fry sand	Pen	S	ML, N
3	1,548	8	2,450	38	37	Bend	Pen	L	A
4	4,069	62	800	38	33	Childress sand	Pen	S	ML, N
5	1,622	34	1,150	44	40	Fry	Pen	S	ML, N
6	2,553	206	1,200	41	39	Cross Cut sand	Pen	S	ML, N
7	8,001	117	1,300	44	40	Fry sand	Pen	S	ML, N
8	3,527	42	1,300	40	38	Fry sand	Pen	S	ML, N
9	4,802	51	1,300	42	40	Fry sand	Pen	S	ML, N
10	4,442	203	1,200	42	40	Blake sand	Pen	S	ML, N
11		302							
12		1,064							
13	1,656	36	1,700	40	38	Cross Plains sand	Pen	S	ML, N
14	3,212	98	400	39	38	Moutray sand	Pen	S	ML
15	3,378	143	700	38	36	Isenhour sand	Pen	S	ML
16	5,568	114	750	39	36	Moutray sand	Pen	S	ML
17	678	960							
18		1,351							
19	2,476	180	400	35	34	Burkett sand	Pen	S	ML
20	3,229	34	1,550	43	40	Cross Cut sand	Pen	S	ML, N
21	1,889	11	1,900	44	40	Gwinnup sand	Pen	S	ML, N
22	7,036	31	2,000	43	41	Gwinnup sand	Pen	S	ML, N
23	3,268	25	1,150	40	38	Fry sand	Pen	S	ML, N
24	5,729	24	2,200	44	40	Canyon, Strawn	Pen	S	A
25	2,675	8	1,500	40	38	Fry sand	Pen	S	ML, N
26	1,838	25	1,450	40	38	Fry sand	Pen	S	ML, N
27	1,656	59							
28		397							
29	1,712	85	300	37	34	Strawn	Pen	S	A
30	2,708	2	3,100	39	35	Bend	Pen	L	MN
31	2,440	46	1,200	42	33	Strawn	Pen	S	MN
32	3,760	58	2,450	42	40	Caddo	Pen	L	A, F
33	5,579	9	3,600	40	38	Bond sand	Pen	S	N
34	2,262	393							
35		508							
36	3,667	96	2,750	44	34	Desdemona	Pen	S	A
37	2,101	3	3,670	37	35		Pen	L	A
38	2,678	105	3,100	41	38	Saddle Creek	Pen	L	A
39		108							
40	292	17	1,900	38	37	Petroleum Producers sand	Pen	S	N
41	1,801	58	2,050	42	37	Petroleum Producers sand and Hope sand	Pen	S, L	A
42	1,326	13	2,040	40	37	King sand	Pen	S	A
43	5,920	91	2,500	39	38	Camp Colorado	Pen	L	MC, N
44	649	16	1,950	41	40	Cook sand	Pen	S	A
45	36	3	2,000	38	37	Cook sand horizon	Pen	L	ML, N
46		9							
47		207							
48	2,318	6	1,800	37	36	Hope sand	Pen	S	N
49	895	99	600	36	34	Cisco	Pen	S	N
50	6,917	199	4,800	40	38	Strawn	Pen	S	N
51	3,047	26	4,800	40	38	Strawn	Pen	S, L	N
52		324							
53	2,166	6	3,950			Bend	Pen	L	N
54	1,255	3	3,200			Bend	Pen	L	N

¹ Footnotes to column heads and explanation of symbols are given on page 291.

TABLE 1.—(Continued)

Line Number	Field	Age, Years to End of 1936	Area Proved, Acres	Total Oil Production, Bbl.				
			Oil	To End of 1936	During 1935	During 1936	Daily Average during Dec. 1936	
55	Strawn.....	22	1,150	2,749,399	64,141	73,929	176	
56	Other fields.....		550	633,616	79,224	41,749		
57	Total Palo Pinto County.....		2,460	4,482,518	143,365	130,060	y	
Shackelford County								
58	Cook.....	11	1,460	13,789,227	891,325	948,377	2,438	
59	Frye.....	11	115	297,284	10,758	8,106	22	
60	Hope.....	13	220	1,142,622	75,519	60,124	153	
61	Ibex.....	15	1,240	2,331,133	33,249	40,483	92	
62	Bluff Creek.....	6	940	1,478,189	303,484	626,788	2,601	
63	Newell.....	11	640	601,580	140,723	103,267	255	
64	Petroleum Producers.....	7	100	119,623	12,269	12,100	35	
65	Simmons-Harvey.....	11	160	253,156	53,484	42,331	153	
66	Tannehill-Matthews.....	9	300	1,975,979	141,005	163,110	415	
67	Other fields.....		7,705	9,083,934	1,360,464	518,841	1,117	
68	Total Shackelford County.....		12,880	31,072,727	3,022,279	2,523,527	7,281	
Stephens County								
69	Curry.....	16	2,580	9,224,145	111,128	87,900	238	
70	Strawn.....	19	850	4,334,955	97,629	96,230	251	
71	Other fields.....		44,570	108,683,027	1,612,192	1,461,634	276	
72	Total Stephens County.....		48,000	122,242,127	1,820,949	1,645,764	765	
Taylor County								
73	Miscellaneous.....		170	217,044	35,013	28,446	71	
Throckmorton County								
74	Woodson (Deep).....	12	260	1,694,713	86,294	64,770	170	
75	Woodson (Shallow).....	11	120	664,341	45,508	39,973	106	
76	Other fields.....		720	565,938	36,752	59,319	209	
77	Total S/2, Throckmorton County.....		1,100	2,924,992	168,554	164,062	485	
Young County								
78	Bunger.....	15	1,040	3,660,595	80,746	66,072	188	
79	Graham.....	10	380	1,649,329	54,342	36,666	70	
80	Graham-Vic.....	6	320	359,330	y	154,421	403	
81	Herron City.....	15	500	1,553,299	16,946	13,716	41	
82	Kisinger.....	7	410	2,278,654	281,539	156,915	220	
83	South Bend.....	19	1,440	10,020,319	159,178	142,011	405	
84	Rathke.....	y	y	y, 332,844	y	332,844	1,718	
85	Other fields.....		13,349	33,459,902	3,605,347	y, 619,708	y	
86	Total Young County.....		17,439	53,314,272	4,198,098	1,522,353	4,045	

TABLE 1.—(Continued)

Line Number	Average Oil Production, Bbl. per Acre	Number of Oil and/or Gas Wells	Depth, Average in Feet	Character of Oil, Approx. Average during 1936		Producing Rock			
	To End of 1936	At End of 1936	Bottoms of Productive Wells	Gravity A.P.I. at 60° F.		Name	Age ¹	Character ²	Structure ¹
		Producing Oil Only		Maximum	Minimum				
55	2,388	153	1,850			Strawn	Pen	S	ML, N
56	1,152	23							
57		185							
58	9,444	357	1,300	38	36	Cook sand	Pen	S	ML, N
59	2,582	56	450	36	34	Frye sand	Pen	S	ML, N
60	5,193	65	1,500	38	36	Hope sand	Pen	S	ML, N
61	1,878	35	3,500	40	38	Caddo limestone	Pen	L	N
62	1,572	143	1,600	39	38	Petroleum Producers sand	Pen	S	ML, N
63	939	103	1,100	38	36	Tannehill sand	Pen	S	ML, N
64	1,196	13	1,650	40	38	Petroleum Producers sand	Pen	S	N
65	1,582	14	1,700	40	38	Petroleum Producers sand	Pen	S	N
66	6,586	64	1,150	39	37	Tannehill sand	Pen	S	ML, N
67	1,177	875							
68		1,725							
69	3,575	51	3,100	39	38	Caddo lime	Pen	L	A
70	5,099	98	1,850	39	37	Strawn	Pen	S	ML, N
71	2,438	582							
72		731							
73	1,276	11		40	35				
74	6,269	10	3,900	39	37	Caddo lime	Pen	L	A
75	5,536	10	2,350	38	36	Canyon-Strawn	Pen	S	ML
76		132							
77		152							
78	3,519	44	2,600	38	36	Strawn sand	Pen	S	A
79	4,340	10	3,900	39	37	Bend-Strawn	Pen	SL	A
80	1,122	21	2,750	39	37	Strawn sand	Pen	S	A
81	3,146	12	2,600	38	36	Strawn sand	Pen	S	ML, N
82	5,557	40	2,500	40	38	Strawn sand	Pen	S	A
83	6,958	76	4,000	41	39	Strawn-Bend	Pen	S	ML, N
84	v	26							
85	v	96							
86		325							

TABLE 2.—Summary of Drilling Operations in North Central Texas

Important Wildcats Drilled in 1936											
	County	Location	Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Initial Production per Day		Choke Fractions of an Inch	Pressure, Lb. per Sq. In.	
							Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing
1	Hamilton	BBB & C, sec. 41	5345	Walnut	Ellenburger	Seaboard No. 1 Dawson		3,310,000	2	1150	55
2	Hamilton	D. Cook	2455	Paluxy	Bend	Seaboard No. 1 Rea		11,690,000		1160	
3	Jones....	TPRR, sec. 44, Blk. 15	2001	Clear Fork	Cisco	Farris & Roberts No. 1 Guitar Tr. Est.	108				

Oil and Gas Development in the Texas Panhandle for the Year 1936

BY T. C. CRAIG*

DURING the year 1936, there were 654 oil wells drilled in the Texas Panhandle, with a total daily initial production of 256,049 bbl. Although 74 more wells were drilled than in the previous year, the total initial production lacked 109,303 bbl. to equal that of 1935. The explanation is that during 1935 most of the drilling was in the granite-wash area, which is much more prolific than the dolomite, in which the major development was done during 1936. Twenty-one oil wells were drilled deeper, increasing their potential 3683 bbl. The total daily oil potential of the field Dec. 31, 1936, as determined by the Texas Railroad Commission, was 834,888 bbl., with a daily allowable production of 71,335 bbl. No overall field decline in production is recognized by the Texas Railroad Commission. A well is tested upon completion to determine its potential production. If the well is then shot with nitroglycerin or is treated with

TABLE 1.—Oil and Gas Production in the Texas Panhandle

Line Number	County	Age, Years to End of 1936	Area Proved, Acres			Total Oil Production, Bbl.			
			Oil and Gas ^a	Gas	Total	To End of 1936	During 1935	During 1936	Daily Average during Nov. 1936
1	Carson.....	15	15,000	235,314	250,314	25,030,561	1,774,395	1,942,154	5,584
2	Gray.....	11	39,800	209,957	249,757	123,849,700	11,200,522	10,902,391	29,472
3	Hartley.....	8	0	29,984	29,984				
4	Hutchinson.....	14	49,000	192,495	241,495	113,846,030	4,617,574	5,488,049	15,397
5	Moore.....	10	2,100	429,827	431,927	3,348,422	465,915	494,925	1,231
6	Potter.....	17	0	143,194	143,194				
7	Wheeler.....	11	8,200	149,615	157,815	10,388,591	3,480,665	3,644,008	8,289
8	Total.....		114,100	1,390,386	1,504,486	276,463,304	21,539,071	22,471,527	59,973

^a Footnotes to column headings and explanation of symbols are given on page 291.

Manuscript received at the office of the Institute April 28, 1937.

* Phillips Petroleum Co., Amarillo, Texas.

acid, it is tested again within 40 to 60 days. Within a period of 70 to 90 days, depending upon whether the well has been given one or two tests, another test must be made to determine the decline in potential or accept a cut in production ranging from 12.5 per cent on a well having initially tested 500 bbl. or less and graduated to 60 per cent on a well having initially tested 3000 bbl. or more. The potential thus established remains

TABLE 1.—(Continued)

Line Number	Total Gas Production, Millions of Cu. Ft.				Number of Oil and/or Gas Wells			Depth, Average in Feet		Oil Production Methods at End of 1936					Pressure, Lb. per Sq. In. ^d		
	To End of 1936	During 1935	During 1936	Maximum Daily during 1936	Completed to End of 1936	During 1936		Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells					Average at End of		
						Completed	Abandoned			Flowing	Pumping	Gas-lift	Air-lift	Miscellaneous	Initial	July ² 1935	July ² 1936
1					606	53	2	3,150	3,050	y	y	y	y	y	430	359.13	354.48
2					1,822	225	16	3,100	3,000	y	y	y	y	y	430	307.01	
3					4	0	0	3,200	2,900						430	415.00	
4					1,718	168	114	3,000	2,900	y	y	y	y	y	430	303.89	282.20
5					206	75	1	3,500	3,400	y	y	y	y	y	430	405.72	401.70
6					46	2	0	2,500	2,300						430	414.11	411.75
7					666	104	7	2,550	2,450	y	y	y	y	y	430	374.53	
8	6,058,471.4 ¹	805,844.1 ¹	622,407.8 ¹	2,219.2 ¹	5,068	627	140										

¹ Gas figures are composite for field. They are the best available but are subject to correction on account of estimates.

² Compilation made by engineers of Texas Railroad Commission.

Line Number	Character of Oil, Approx. Average during 1936						Character of Gas, Approx. Average during 1936		Producing Rock				Deepest Zone Tested to End of 1936	
	Gravity A.P.I. at 60° F.					B.t.u. per Cu. Ft.			Gal. Gasoline per M. Cu. Ft.	Name	Age ¹	Character ²	Structure ³	Name
	Maximum	Minimum	Weighted Average	Sulphur, Per Cent	Base ⁴									
1	45	32	39	0.6	M	1,094	0.43	Big Lime series (Wichita-Albany) Pen (undifferentiated)	Per Pen	D, Do GW	Af	Granite wash (Penn)		
2	45	31	39	0.4	M	1,103	0.70	Big Lime series (Wichita-Albany) Pen (undifferentiated)	Per Pen	D, Do GW	Af	Granite wash (Penn)		
3								Big Lime series (Wichita-Albany) Pen (undifferentiated)	Per Pen	D, Do GW	Af	Granite wash (Penn)		
4	39	29	35	0.8	M	1,106	0.47	Big Lime series (Wichita-Albany) Pen (undifferentiated)	Per Pen	D, Do L, GW	Af	Arbuckle	5,333	
5	36	30	31	0.8	M	1,056	0.30	Big Lime series (Wichita-Albany) Pen (undifferentiated)	Per Pen	D, Do L, GW	Af	Arbuckle	8,013	
6						1,069		Big Lime series (Wichita-Albany) Pen (undifferentiated)	Per Pen	D, Do GW	Af	Granite wash (Penn)		
7	44	30	37	0.4	M	1,070	0.28	Big Lime series (Wichita-Albany) Pen (undifferentiated)	Per Pen	D, Do GW	Af	Arbuckle	2,957	
8														

^a Dry gas, 30 in. at 60° F.

in effect over the life of the well unless a test is requested by the operator or by the commission.

Dry Gas.—During the year, 156 wells were drilled, with a combined open flow of 5,348,800,000 cu. ft. Twenty-eight depleted oil wells were converted into gas wells for a total open flow of 231,590,000 cu. ft. The total new gas developed during the year was 5,580,390,000 cu. ft. The pipe-line companies withdrew a total of 188,912,177,000 cu. ft. of gas from the reservoir, or a daily average of 516,156,221 cu. ft.—an increase of 35,431,587,000 cu. ft. over that for the year 1935.

TABLE 2.—*Summary of Drilling Operations in the Texas Panhandle*

Important Wildcats Drilled in 1936

	County	Location			Total Depth, Ft.
		Sec.	Block	Survey	
1	Childress.....	544	H	W. & N. W.	3001
2	Collingsworth.....	8	13	H. & G. N.	2254
3	Cottle.....	546	H	W. & N. W.	6002
4	Gray.....	21		L. L. Erwin	2860
5	Gray.....	9	B-2	H. & G. N.	3124
6	Gray.....	9	H	A. Wallace	2995
7	Hall.....	4	H	J. H. Stephens	8017
8	Hartley.....	20	Sub 22	Capitet Syn.	4600
9	Wheeler.....	86	13	H. & G. N.	4361

Important Wildcats Drilled in 1936

	Surface Formation	Deepest Formation Tested	Drilled by	Initial Production Per Day	Pressure, Lb. per Sq. In.	Remarks
				Gas, Millions Cu. Ft.	Casing	
1	Blaine	Panhandle Big lime	Fain Drilling Co. et al.	2.08	350	Dry and abandoned.
2	Blaine	Granite wash	Tom Hunter et al.			Dry and abandoned.
3	Blaine	Cisco	Alma Oil Co.			Dry and abandoned.
4	Tertiary	Granite	Foster et al.			Dry and abandoned.
5	Quartermaster	Granite	J. R. Phillips			Dry and abandoned.
6	Quartermaster	Granite wash	Warner Oil Co.			Dry and abandoned.
7	Blaine	Arbuckle	Phillips Pet., Co.			Dry and abandoned.
8	Tertiary	Panhandle Big lime	O. V. Beck			Dry and abandoned.
9	Quaternary	Granite wash	Rogers et al.			Dry and abandoned.

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1936.....	163	6
Number of oil wells completed during 1936.....	472	
Number of gas wells completed during 1936.....	155	1
Number of dry holes completed during 1936.....	21	4

Natural Gasoline.—Of the 41 natural gasoline extraction plants, 39 operated throughout the year; the combined capacity being 2,079,500,000 cu. ft. per day. The total amount of gas processed during the year was 389,016,500,000 cu. ft., or a decrease of 206,906,023,000 cu. ft. under that of the year 1935.

Carbon Black.—There are 31 carbon-black plants in the Panhandle, two of which were shut down during the entire year. The 29 plants operating utilized 224,862,800,000 cu. ft. of gas, producing approximately 10,472,992 lb. of carbon black.

Refineries.—The total capacity of all refineries in the Panhandle is approximately 60,800 bbl. daily. The total runs to refineries for the year were 11,823,613 bbl., or a daily average of 32,305 barrels.

Storage.—The total storage capacity decreased 417,000 bbl.—from 21,612,500 to 21,195,500 bbl. The total oil in storage decreased 4,501,727 bbl.—from 12,511,389 to 8,009,662 barrels.

New Development.—No discoveries were made during the year. This is the first time in the history of the field that nothing new has been found during an annual period.

Wildcats.—Nine wildcat tests were drilled, all failures except the Hunter et al. well in Collingsworth County, Texas, which encountered a noncommercial amount of gas. Two important wildcats were drilling at the close of the year; the Phillips Petroleum Company's No. 1 Porter, sec. 35, bl. A-8, H. & G. N. survey, Wheeler County, Texas, was drilling at 7113 ft. in granite wash, the objective being the Ordovician, and the L. S. Hobbs No. 1 Pearson-Hitch, sec. 290, bl. 2, G. H. & H. survey, Hansford County, Texas, a Permian test, was drilling at 2435 feet.

Oil and Gas Development in South Texas during 1936

BY HARRY H. NOWLAN,* MEMBER A.I.M.E.

A HEAVY development campaign progressed during the year 1936 in South Texas¹, following up important discoveries made in 1935. Oil and gas wells completed during the year were 1473 against 704 in 1935. The drilling program reached its peak of operations in June in consequence of offset requirements made necessary principally in Duval County in the Seven Sisters, Loma Novio, Lopez and Cole fields. There were six new fields discovered during 1936 as follows: Rhode in McMullen County; Peters, El Mesquite and North Kohler in Duval County; Wood in Starr County and Colorado in Jim Hogg County. No discovery of unusual consequence was made during the year. The pools mentioned above are simply in the primary stages of development.

The most intensive exploratory work during the year was in Duval, Webb and Zapata Counties. Considerable activity also prevailed in Starr and Brooks Counties. Much significance is attached to the California Company's discovery in the Alta Mesa field in Brooks County, which is considered to be a deep-seated salt dome. The Comitas field, in Zapata County, developed some surprisingly good production in a shallow sand at 900 ft. and is being followed by a heavy wildcat campaign throughout that area in search of like production.

In Starr County an active wildcat campaign is in progress in a continued effort to find new fields northwest of the Sam Fordyce field, in Hidalgo County. This play continues in a northerly direction through Starr and Jim Hogg Counties.

NEW FIELDS

Rhode.—The Rhode field, in southeastern McMullen County, was opened in May by the Magnolia Petroleum Co. with a gas well in the Whitsett (Upper Jackson) sand at a depth of 1810 to 1822 ft., this test is located in the southeast corner of sec. 86 on the Rhode ranch. Four gas wells have been completed, proving up a gas area of 1000 acres, more or less. Development will be slow because of lack of market for the gas.

Published by permission of the Darby Petroleum Corporation. Manuscript received at the office of the Institute March 9, 1937.

* Chief Geologist, Darby Petroleum Corporation, San Antonio, Texas.

¹ Formerly called Southwest Texas

TABLE 1.—Oil and Gas Production in South Texas (Formerly Called Southwest Texas)

Line Number	Field, County	Age, Years to End of 1936	Area Proved, Acres			Total Oil Production, Bbl.				Total Gas-Production, Millions Cu. Ft.	
			Oil	Gas	Total	To End of 1936	During 1935	During 1936	Daily Average during Nov. 1936	To End of 1936	During 1935
1	Reiser, Webb.....	23	0	0	1,280	Gas	Gas	Gas	0	y	0
2	Charco Redondo, Zapata.....	23	336	0	336	142,161	2,579	3,606	43.0	0	0
3	Jennings, Zapata.....	22	0	0	320	Gas	Gas	Gas	0	y	403
4	Crowther, McMullen.....	17	160	0	160	x	0	0	0	0	0
5	Callihan, McMullen.....	17	300	y	290	582,000	31,276	68,430	191	y	y
6	Mirando Valley, Zapata.....	15	115	y	120	235	628,351	10,476	10,047	27	y
	Carolina-Texas, Webb										13.3
7	1,200-ft. sand.....	15	0	y	80	80	Gas	Gas	0	0	0
8	2,000-ft. sand.....	14	0	y	480	480	Gas	Gas	0	y	y
9	2,600-ft. sand.....	11	70	y	480	550	92,492	4,818	2,245	4	y
10	3,000-ft. sand.....	13	40	y	400	440	157,896	3,258	1,350	4	y
11	5,000-ft. sand.....	2	0	y	40	40	Gas	Gas	0	y	y
12	Total.....	15	110	y	1,480	1,590	304,669	8,076	3,595	8	y
13	Mirando City, Webb.....	15	1,430	y	420	1,850	8,609,010	137,821	143,362	372	y
14	Aviator, Webb.....	14	955	y	320	1,275	5,493,551	154,718	143,237	389	y
15	Leaseholders, Webb.....	14	10	0	0	10	x	0	0	0	0
16	Henne-Winch-Fariss, Jim Hogg.....	12	720	y	440	1,160	3,253,498	7,160	1,126	0	y
	Cole, Webb										0
17	1,700-ft. sand.....	12	65	y	4,000	4,065	179,856	12,288	12,200	30	y
18	2,300-ft. sand.....	9	0	y	1,280	1,280	Gas	Gas	0	y	y
19	2,800-ft. sand.....	6	1,530	y	120	1,650	1,839,840	326,242	1,183,759	3,550	y
20	2,900-ft. sand.....	2	0	y	80	80	Gas	Gas	0	y	y
21	3,400-ft. sand.....	2	640	0	80	720	1,716,175	1,138,413	440,199	1,271	y
22	Total.....	12	2,235	y	5,560	7,795	3,735,871	1,476,943	1,636,158	5,851	y
23	Randado, Jim Hogg.....	11	733	y	150	883	4,273,401	132,476	113,507	285	y
24	Piedras Pintas, Duval.....	11	30	y	0	30	145,070	12,129	3,049	0	0
25	Alworth, Jim Hogg.....	10	40	y	30	70	27,154	1,151	320	0	0
26	Kohler, Duval.....	10	170	y	1,840	2,010	499,662	44,012	38,861	119	y
27	West Cole, Webb.....	9	330	y	960	1,290	3,130,319	286,083	208,629	462	y
28	Cuellar, Zapata.....	9	315	y	160	475	2,446,993	42,146	42,522	83	y
	Driscoll, Duval										0
29	2,400-ft. sand.....	9	0	y	600	600	Gas	Gas	0	y	y
30	2,900-ft. sand.....	8	200	y	400	600	450,744	20,444	21,000	75	y
31	3,300-ft. sand.....	2	150	y	400	550	194,153	62,310	114,753	395	y
32	Total.....	9	350	y	1,400	1,750	644,897	82,754	135,753	470	y
33	Albercal, Webb.....	8	320	y	160	480	2,436,508	38,246	31,075	62	y
34	Government Wells, Duval.....	8	8,040	y	430	8,470	28,373,750	6,393,169	5,810,076	14,605	y
35	Palangana, Duval.....	8	40	y	0	40	y	0	y	0	0
36	Martinez, Zapata.....	8	0	y	600	600	Gas	Gas	0	y	0
37	Roma, Starr.....	7	10	y	80	90	15,282	2,355	956	0	0
	Escobas, Zapata										0
38	1,000-ft. sand.....	6	0	y	120	120	Gas	Gas	0	y	y
39	1,200-ft. sand.....	7	1,400	y	90	1,490	4,925,976	604,164	582,009	1,663	y
40	1,400-ft. sand.....	6	1,800	y	120	1,920	1,285,993	62,671	64,890	216	y
41	Total.....	7	3,200	0	330	3,530	6,211,969	666,835	646,899	1,879	y
42	S. R. C., Duval.....	6	80	y	0	80	203,371	15,937	3,847	0	0
43	Los Olmos, Starr.....	5	160	y	0	160	472,492	71,742	55,943	167	0
44	Wentz, McMullen.....	4	0	y	80	80	Gas	Gas	0	y	y
45	Sarnosa, Duval.....	4	620	y	40	660	1,525,554	320,323	319,965	757	27.5
46	Rio Grande City, Starr.....	4	160	0	0	160	228,930	72,514	83,373	220	0
47	Jacobs, McMullen.....	4	1,010	0	10	1,020	793,000	180,315	242,282	700	0
48	Laurel, Webb.....	4	220	y	320	540	666,372	32,262	10,723	29	y
49	Villa, Zapata.....	4	0	0	80	80	Gas	Gas	0	0	0
50	Clark-Cowden, Jim Hogg.....	4	80	0	40	120	Gas	Gas	0	0	0
51	Smith Hunter, Duval.....	4	0	0	40	40	Gas	Gas	0	0	0
52	Moca, Webb.....	4	80	0	0	80	592,791	228,931	147,426	399	0
53	Blas Uribe, Zapata.....	3	0	0	80	80	Gas	Gas	0	0	0
54	Ignacio, Duval.....	3	10	0	0	10	x	0	0	0	0
55	Cuevitas, Starr.....	3	360	y	400	760	383,398	154,327	154,942	450	10.4
56	Hoffman, Duval.....	3	800	0	100	900	287,066	5,486	281,580	1,048	0
	North Kohler, Duval										0
57	1,700-ft. sand.....	3	0	0	80	80	Gas	Gas	0	0	0
58	2,400-ft. sand.....	3	10	0	320	330	9,125	0	9,125	30	y
59	Total.....	3	10	0	400	410	9,125	0	9,125	30	y
											402.7

a Footnotes to column heads and explanation of symbols are given on page 291.

TABLE 1.—(Continued)

Peters.—The Peters field, in western Duval County, was opened by the Mills Bennett Production Co. in June with an oil well in the McElroy (Middle Jackson) sand at a depth of 1757 to 1760 ft. Several additional wells have been completed but development is not active.

El Mesquite.—In July the Rogers Oil & Gas Co. opened the El Mesquite field, in southwestern Duval County, with a 10-bbl. oil well in the McElroy (Middle Jackson) sand at a depth of 2850 to 2862 ft. Several dry holes have been completed in the area since that time and undoubtedly further development will be retarded in consequence thereof.

Wood.—Ed Leach et al. completed a gas well in the Frio (Oligocene) sand at 963 to 975 ft. on July 23, thereby opening the Wood field in southern Starr County.

Colorado.—This field is in southwestern Jim Hogg County. The first well was completed in the Cockfield (Eocene) sand at 3010 to 3017 ft., in August, by J. H. Meek, and produced about 65 bbl. per day of 47° gravity oil. One dry hole has been completed since and one test is drilling.

North Kohler.—The North Kohler field, in western Duval County, was opened in November by the Humble Oil and Refining Co., with an

TABLE 1.—(Continued)

Line Number	Field, County	Age, Years to End of 1936	Area Proved, Acres				Total Oil Production, Bbl.				Total Gas Production, Millions Cu. Ft.	
			Oil	Oil and Gas*	Gas	Total	To End of 1936	During 1935	During 1936	Daily Average during Nov. 1936	To End of 1936	During 1935
60	Barbacoas, Starr	2	0	0	20	20	Gas	Gas	Gas	0	y	y
61	900-ft. sand.....	3	20	y	160	180	21,990	15,001	4,330	0	y	y
62	2,400-ft. sand.....	3	20	0	180	200	21,990	15,001	4,330	0	y	y
	Total.....											
63	Eagle Hill, Duval	3	200	0	0	200	507,457	155,006	130,782	307	0	0
64	1,500-ft. sand.....	2	40	0	0	40	22,176	9,217	7,010	27	0	0
65	2,100-ft. sand.....	3	240	0	0	240	529,633	164,223	137,792	334	0	0
	Total.....											
66	Lopeño, Zapata	2	0	0	1,000	1,000	Gas	Gas	Gas	0	y	y
67	Comitas, Zapata	2	675	0	0	675	267,273	2,538	252,947	1,522	0	0
68	Labbe, Duval	2	0	0	40	40	Gas	Gas	Gas	0	0	0
69	Colmena, Duval	2	60	0	40	100	14,811	0	14,811	90	0	0
70	Loma Novio, Duval	2	7,500	0	210	7,710	5,629,565	782,644	4,846,921	15,051	y	7.7
71	Piedra de Lumbre, Duval	1	550	0	0	550	207,445	7,714	199,731	665	0	0
	Seven Sisters, Duval											
72	2,200-ft. sand.....	1	120	0	10	130	140,727	11,127	129,600	265	0	0
73	2,400-ft. sand.....	1	3,680	0	0	3,680	1,885,765	115,536	1,770,229	7,351	0	0
74	2,700-ft. sand.....	0	400	0	0	400	92,435	0	92,435	365	0	0
75	Total.....	1	4,200	0	10	4,210	2,118,927	126,653	1,992,264	7,981	0	0
76	Loma Alto, McMullen	1	20	0	0	20	40,766	12,385	28,381	72	0	0
77	Lopez, Webb	1	3,365	0	0	3,365	1,435,766	62,737	1,373,029	5,984	0	0
78	Peters, Duval	0	100	0	0	100	18,962	0	18,962	203	0	0
79	Colmena, Duval	0	60	0	0	60	11,412	0	11,412	133	0	0
80	Alta Mesa, Brooks	0	50	0	0	50	6,908	0	6,908	107	0	0
81	Colorado, Jim Hogg	0	10	0	0	10	513	0	513	0	0	0
82	Loma Vista, Duval	0	10	0	0	10	1,664	0	1,664	0	0	0
83	Total.....		40,399		19,440	59,839	86,367,569	11,786,447	19,238,079	59,787		

oil well in the McElroy (Middle Jackson) sand at 2613 to 2642 ft. Inasmuch as the Humble owns most of the acreage surrounding this well, the development will probably not be rapid.

WILDCATS

Approximately 300 abandonments are recorded for 1936, many of which were wildcat tests drilled in an attempt to extend the productive areas of the Mirando, Government wells and Loma Novio sands of the Jackson. No outstanding deep dry holes were drilled during the year, probably because of the extensive program carried out in an effort to find more prolific shallow production.

OUTLOOK FOR 1937

The drilling campaign starting the year 1937 is not so heavy as that in 1936, since no important discoveries were made and the extensive pools opened in 1935 are about drilled up. However, wildcat activity is rather extensive in all counties in the district and tests are being drilled deeper than formerly. Satisfactory geophysical work is being done in the eastern part of the area and since eastern Duval, all of Brooks, and the eastern

TABLE 1.—(Continued)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells							Depth, Average in Feet	Oil Production Methods at End of 1936		Pressure, Lb. per Sq. In. ^a		Character of Oil, Approx. Average during 1936							
	During 1936	Maximum Daily during 1936	Completed to End of 1936	During 1936		At End of 1936					Number of Wells	Average at End of		Gravity A.P.I. at 60° F.			Base ^c					
				Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas ^b	Producing Gas Only	Total Producing		Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Initial		1935	1936	Maximum	Minimum	Weighted Average
60	y	y	3	0	0	0	0	0	3	3	715	685	0	0	z	0	0	0	0	0	P	
61	y	y	9	3	0	0	2	0	5	7	2,455	2,440	1	1	z	y	y	y	y	27.7	P	
62	y	y	12	3	0	0	2	0	8	10											P	
63	0	0	16	0	0	0	16	0	0	16	1,490	1,480	1	15	x	y	y	y	y	22.5	P	
64	0	0	2	0	0	0	2	0	0	0	2,147	2,136	0	0	z	y	y	y	y	22.5	P	
65	0	0	18	0	0	0	2	16	0	18											P	
66	y	y	11	0	0	0	0	0	11	11	2,180	2,132	0	0	z	0	0	0	0	0	P	
67	0	0	112	104	0	0	106	0	0	106	840	832	52	54	x	y	y	y	y	22.5	P	
68	0	0	4	1	0	5	0	0	5	5	2,460	2,453	0	0	z	0	0	0	0	0	P	
69	0	0	5	2	0	0	3	0	2	5	1,505	1,486	0	0	z	0	0	0	0	0	P	
70	y	y	680	462	0	10	636	0	5	641	2,705	2,680	428	213	x	y	y	y	y	24.5	P	
71	0	0	34	32	0	3	30	0	0	30	1,950	1,930	15	15	x	y	y	y	y	22.5	P	
72	0	0	12	9	0	0	12	0	0	12	2,213	2,193	8	4	x	y	y	y	y	22.5	P	
73	0	0	338	301	0	3	314	0	0	314	2,486	2,470	298	16	x	y	y	y	y	22.5	P	
74	0	0	15	15	0	0	15	0	0	15	2,685	2,666	15	0	y	y	y	y	y	22.5	P	
75	0	0	365	325	0	3	341	0	0	341											P	
76	0	0	2	0	0	0	2	0	0	2	2,194	2,186	2	0	x	y	y	y	y	22.5	P	
77	0	0	271	245	0	0	260	0	1	261	2,183	2,159	210	51	x	y	y	y	y	22.5	P	
78	0	0	13	13	0	2	6	0	2	8	1,760	1,757	6	0	z	y	y	y	y	22.5	P	
79	0	0	5	5	0	0	3	0	1	4	1,505	1,486	3	0	z	0	y	y	y	22.5	P	
80	0	0	3	3	0	0	1	0	0	1	3,047	3,022	1	0	z	0	y	y	y	24	P	
81	0	0	1	1	0	1	0	0	0	0	3,017	3,010	0	1	x	0	y	y	y	46	P	
82	0	0	1	0	0	0	1	0	0	1	2,921	2,914	0	1	x	0	y	y	y	22.5	P	
83				5,167	1,473	43	224	3,361		287	3,648		1,693	1,653							P	

portion of Jim Hogg and Starr Counties are in a salt-dome province, undoubtedly some favorable results may be anticipated.

ACKNOWLEDGMENTS

The writer wishes to acknowledge certain courtesies extended for contributions and data for the compilation of this paper to: Messrs. W. K. Esgen, Milton Hruby, Herschel H. Cooper, Olin H. Bell, Rae Preece, E. L. Porch, and many others.

TABLE 1.—(Continued)

[illegible]

TABLE 2.—*Summary of Drilling Operations in South Texas District*

Important Wildcats Drilled in 1936							
County	Location	Total Depth, Ft.	Deepest Horizon Tested	Drilled by	Initial Production per Day		Remarks
					Oil, U. S. Bbl.	Gas, Millions Cu. Ft.	
1 Brooks.....	Alta Mesa field No. 1	3028	Frio	California Co.		20	T.D. 8022 P.B. 3029.
2 Duval.....	Garcia Colmena Extension No. 2 D.C.R.C.	1592	Whitsett	Conservative Oil Co.	27		
3	Palangana Dome No. 1 A. Schallert	2744		Frank Gravis	500		
4	West Side Gov't. Wells field No. 1 Herman Wendt	2392	McElroy	Magnolia Pet. Co.	300		
5	Labbe Field Ext. No. 1 Labbe Sec. 221	2945	McElroy	Magnolia Pet. Co.		Gas. (no gauge)	810 R.P. D. & A. 7016. D. & A. 6022
6	S.E. Duval Co. No. 1 Sevier	7016		Benedum & Trees			
7	S.E. Duval Co. No. 1 Book	6022		Santa Clara			
8 Jim Hogg	Colorado field No. 1 A. Martinez	3017	Cockfield	J. H. Meek Jr.	70		T.D. 3153 P.B. 1822. T.D. 4003.
9 Jim Wells....	San Diego field No. 1 Hawkins	2957		Houston Oil Co.		1½	
10 McMullen....	Rhode field No. 2 Kincaid	1822	Whitsett	Magnolia Pet. Co.		20	
11 Starr.....	San Domingo field No. 3 Roos and Bennett	2417	McElroy	J.H.Clopton		15	

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1936.....	94	144
Number of oil wells completed during 1936.....	1422	
Number of gas wells completed during 1936.....	51	
Number of dry holes completed during 1936.....	292	

Petroleum Development and Production in West Texas in 1936

BY H. W. MATHEWS* AND J. D. WHEELER,† MEMBER A.I.M.E.

THE increased activity in West Texas, which started in 1933, has continued through 1936 at a constantly accelerated rate. During 1936 there were 1442 wells completed in the area as compared with 700 in 1935 and 468 in 1934. Of these completions, 1313 were producers with a total 24-hr. potential in excess of 1,750,000 bbl. From among the 1442 wells, eight are considered to be discovery wells for new West Texas fields.

NEW FIELDS

Bennett.—The Bennett field, which added Yoakum County to the oil-producing counties of West Texas, was actually indicated as an oil-producing area during 1935, but the discovery well, Honolulu Oil Corporation, Ltd. and Cascade Petroleum Company's Bennett No. 1, was not given a production test until April 1936. The discovery well made 15 bbl. per hour through $\frac{3}{4}$ -in. choke with a plugged-back total depth of 5264 ft. First oil in the hole was from 5088 to 5090 ft., which is several hundred feet below the top of Permian lime. Producing limits of the field are unknown, as the second test had not reached the pay at the close of the year.

Henderson.—To date indications are that the Henderson pool, in northern Winkler County, is the most prolific area opened during 1936. This field, which lies to the north of the old Hendrick pool, is producing from the same reef-type dolomitic lime producing in the older field. The Henderson field was opened by the completion of R. H. Henderson, J. B. Walton-Humble 1-A in April 1936 for a natural flow of 2306 bbl. per day through tubing. Total depth of the discovery well is 3049 ft. Later development has indicated the productive area to be a rather narrow zone running slightly west of north. Present area of from 1000 to 1500 acres has been proved for production.

Keys and Emperor.—The Keys and Emperor pools in the belt of sand pools running across Winkler County appeared for the first time on State proration schedules during 1936. This report considers these pools as links in joining the belt of sand production across Winkler County, for

Manuscript received at the office of the Institute March 29, 1937.

* The Standard Oil Company of Texas, Iraan, Texas.

† The Ohio Oil Company, Iraan, Texas.

TABLE 1.—*Oil and Gas Production in West Texas for 1936*

Line Number	Field, County	Age, Years to End of 1936	Area Proved, Acres				Total Oil Production, Bbl.	
			Oil	Oil and Gas ^a	Gas	Total	To End of 1936	During 1935
1	Toyah, Reeves	17	640±	0	0	640±	6,500±	100±
2	Westbrook, Mitchell	16	4,000	0	0	4,000	8,098,065	344,992
3	Big Lake, Regan	13	y	y	y	y	x	x
4	2400-ft. } Permian ¹	13	3,000	0	0	3,000	80,436,054	1,935,987
5	3000-ft. } Ordovician	8	1,300	0	0	1,300	24,699,395	1,582,775
6	Emerald (Garza), Garza	12	320	0	0	320	59,688	7,627
7	Ira (Northwest), Scurry	12	640	0	0	640	100,184	8,817
8	Church-Fields-McElroy-McClintic, Crane-Upton	11	13,500	0	0	13,500	100,402,526	4,062,666
9	Chalk-Roberts, Howard-Glasscock	10	1,200	0	0	1,200	4,108,152	214,677
10	1400-ft. pay	11	4,000	0	0	4,000	11,001,037	782,218
11	1700-ft. pay	8	8,000	0	0	8,000	30,554,973	4,341,190
12	2200-ft. pay	9	1,000	0	0	1,000	6,373,292	536,305
13	2500-ft. pay	9	3,200	0	0	3,200	20,675,572	900,733
14	3000-ft. pay	11	6,500	0	0	6,500	5,247,193	1,162,966
15	Iatan-Denman, Mitchell-Howard	11	9,160	0	0	9,160	31,569,747	2,028,050
16	McCamey-Hurdle, Upton-Crane							
17	North Cowden, Crane ²			x	x		x	x
18	Edwards, Crane ²			x	x		x	x
19	Hurdle, Crane			x	x		x	x
20	Wheat, Loving	11	4,500	0	0	4,500	6,345,199	658,977
21	World-Powell, Crockett	11	2,000	0	0	2,000	4,957,983	325,259
22	Yates							
23	Lime, Pecos-Crockett	10	20,000±	0	0	20,000	223,100,667	15,197,819
24	Sand, Pecos	3	700	0	0	700	231,245	75,585
25	Tobarg, Pecos	7	1,200	0	0	1,200	3,855,080	644,519
26	Hendrick, Winkler	10	9,200	0	0	9,200	184,129,165	5,700,186
27	Penn, Ector	7	6,960	0	0	6,960	15,261,126	2,051,447
28	Leck, Winkler	9	500	0	0	500	3,144,757	223,401
29	Scarborough-Kermitt-Halley, Winkler							
30	Scarborough ³	11,000±	0	0	11,000±	5,330,071	935,821	x
31	Bashara			x	x		x	x
32	Keyes			x	x		578,746	x
33	Emperor			x	x		x	x
34	Brown-Altman			x	x		x	x
35	Halley			x	x		x	x
36	Sealey			x	x		x	x
37	Waddell-Henderson, Crane	9	6,000	0	1,000	7,000	886,083	99,016
38	Grayson, Regan	8	640	0	0	640	460,045	67,770
39	Pecos Valley, Pecos	8	1,500	0	80	1,580	581,335	73,599
40	Pryor (Richard), Pecos	8	160	0	0	160	27,229	8,524
41	Taylor Link, Pecos							
42	Lime	8	1,000	0	0	1,000	3,847,901	420,273
43	Sand	7	450	0	0	450	465,791	15,000x
44	Ward Co., Ward	30,000	x	1,000	31,000	25,841,044	6,269,575	x
45	North Ward			x	x		x	x
46	Eates			x	x		309,063	0
47	Dobbs			x	x		6,924	0
48	South Ward			x	x		x	x
49	Shipley			x	x		x	x
50	Monroe			x	x		x	x

^a Footnotes to column heads and explanation of symbols are given on page 291.¹ 2400 and 3000-ft. pays no longer separated on production records by operating companies. All Permian production credited to 3000-ft. pay for 1936. Big Lime and Big Lake lime are same zone.² Production and well, not included in McCamey-Hurdle pool during 1936. Production before 1936 included with McCamey field.³ The Scarborough field should probably be grouped with Leck and Sayre.

as the year closed the wells in the south end of the Keys pool were being completed as direct offsets to wells in the north end of the Brown-Altman pool.

TABLE 1.—(Continued)

Line Number	Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells										Depth, Average in Feet	
	During 1936	Daily Average during Nov. 1936	To End of 1936	During 1935	During 1936	Maximum Daily during 1936	Completed to End of 1936	During 1936		At End of 1936							Bottoms of Productive Wells	To Top of Productive Zone
								Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas ^a	Producing Gas Only	Total Producing				
1	0	0	0	0	0	0	35	0	y	y	y	0	0	0	0	100	100	
2	319,980	1,111	x	x	x	x	136	0	0	19	106	0	0	106	3,000	2,800		
3	x	x	x	x	x	x	21	0	1	0	y	0	0	y	2,500	2,375		
4	1,931,503	5,096	x	x	x	x	261	0	0	0	201	0	0	201	3,000	2,960		
5	1,095,899	2,363	y	y	y	y	24	0	2	3	16	0	0	16	8,900	8,200		
6	18,304	114	x	x	x	x	8	1	0	0	8	0	0	8	2,600	2,510		
7	12,199	3	x	x	x	x	9	2	0	0	9	0	0	9	2,395	2,325		
8	4,491,732	11,530	x	x	x	x	414	31	0	0	414	0	0	414	3,000	2,800		
9	466,000x	1,175	x	x	x	x	71	20	0	0	70	0	0	70	1,400	1,280		
10	650,000x	1,635	x	x	x	x	266	0	0	0	264	0	0	264	1,750	1,650		
11	3,907,000x	11,751	x	x	x	x	230	21	0	0	230	0	0	230	2,300	2,150		
12	620,000x	1,560	x	x	x	x	49	8	0	0	49	0	0	49	2,600	2,500		
13	1,100,000x	2,764	x	x	x	x	112	14	0	0	95	0	0	95	3,000	2,900		
14	2,291,054	7,124	x	x	x	x	188	62	0	1	187	0	0	187	2,800	2,450		
15	3,040,080	9,000	x	x	x	x	555	106	y	0	555	0	0	555	2,400	2,000		
16	2,166,279	5,300													4,400	3,950		
17	2,879	10													3,720	3,500		
18	14,358	145													2,100	2,000		
19	604,496	1,418	x	x	x	x	94	5	1	15	78	0	0	78	4,304	4,297		
20	390,024	1,160	x	x	x	x	61	5	1	0	39	0	0	39	2,550	2,450		
21	12,214,156	24,440	11,442	3,202	2,828	10.5	515	41	1	0	514	0	0	514	1,450	1,310		
22	96,846	174	x	x	x	x	10	3	0	0	10	0	0	10	1,100	900		
23	777,366	2,090	x	x	x	x	172	53	1	0	172	0	0	172	445	400		
24	4,791,768	11,900	x	x	x	x	625	0	y	y	392	0	0	392	2,900	2,600		
25	2,169,267	5,472	16,508	2,190y	3,571	7.8	146	17	1	0	144	0	1	145	3,700	3,590		
26	161,361	324	x	x	x	x	16	0	0	0	10	0	0	10	3,100	3,000		
27	2,204,674	8,160	x	x	x	x	322	231	7	0	322	0	0	322	3,300	2,800		
28	649,732	1,800	x												3,500	2,950		
29	10,361	26	x												3,450	3,350		
30	578,746	2,905	x												3,000	2,800		
31	286,695	904	x												3,100	2,833		
32	434,482	1,780	x												3,250	3,200		
33	72,942	260	x												3,200	3,100		
34	177,666	453	x												3,200	3,100		
35	746,199	1,143	y	y	y	y	29	15	y	1	23	0	2	25	3,540	3,200		
36	59,486	161	x	x	x	x	5	0	0	0	5	0	0	5	3,100	3,050		
37	137,371	387	x	x	x	x	52	11	0	0	52	0	0	52	1,600	1,300		
38	1,200	0	x	x	x	x	3	0	0	0	2	0	0	2	1,400	1,385		
39	433,265x	1,000	x	x	x	x	50	2	2	0	48	0	0	48	1,675	1,630		
40	15,000x	42	x	x	x	x	8	0	0	0	8	0	0	8	1,000	970		
41	8,957,515	27,485	x	x	x	x	834	313	4	x	819	y	11	830	3,100	2,400		
42	2,951,948	7,500	x												3,600	3,300		
43	309,063	2,574	x												2,950	2,450		
44	6,924	23	x												2,570	2,555		
45	5,083,173	13,410	x												3,000	2,350		
46	597,252	1,670	x												3,100	3,075		
47	9,155	25	x												4,675	4,665		

Estes.—The Estes field, in Ward County, is another new field for proration purposes, but in the production tables accompanying this report it is grouped with other sandy lime fields of Ward County. This new productive area lies between the Grand Falls or South Ward district

TABLE 1.—(Continued)

Line Number	Oil Production Methods at End of 1936						Injection into Reservoir	Pressure, Lb. per Sq. In. ^d			Character of Oil, Approx. Average during 1936						Character of Gas, Approx. Average during 1936	
	Number of Wells					Initial		Average at End of		Gravity A.P.I. at 60° F.								
	Flowing	Pumping	Gas-lift	Air-lift	Miscellaneous			1935	1936	Maximum	Minimum	Weighted Average	Sulphur, Per Cent	Bases				
1	y	y	0	0	0	0	x	0	0	27	25	26	1.7	M	x	x		
2	0	106	0	0	0	0	e1,000x	y	y	y	y	35	2.5	M,A	y	y		
3	y	y	y	y	y	0	x	x	x	y	y	36	0.4	M	y	y		
4	0	201	0	0	0	0	x	x	x	y	y	36	0.4	M	y	4.0		
5	12	0	4	0	0	0	e3,600	x	x	69	41	44	0.2	P	1,200	0.9		
6	0	8	0	0	0	0	x	x	x	40	38	39	y	y	y	y		
7	0	9	0	0	0	0	x	x	x	25	25	25	2.1	M	y	y		
8	86	328	y	y	y	0	e725	y	y	33	30	32	2.5	M	1,100	1.7		
9	0	70	0	0	0	0	x	x	x	x	x	33	1.0	y	y	y		
10	0	264	0	0	0	0	x	x	x	x	x	32	0.8	y	x	1.8		
11	0	230	0	0	0	0	x	x	x	33	30	30	1.6	y	y	y		
12	0	49	0	0	0	0	x	x	x	x	x	27	3.4	y	y	y		
13	0	95	0	0	0	0	x	x	x	x	x	27	2.0	y	y	y		
14	6	181	0	0	0	0	e500	e500	34	30	32	2.0	M	y	y	y		
15	5	550	0	0	0	0	x	x	x	y	y	28	2.0	M	x	x		
16		28	0	0	0	0												
17		1	0	0	0	0												
18	0	7	0	0	0	0												
19	74	4	0	0	0	0	e1,650	e1,250	e900	39	37	38	0.2	PM	1,000	1.0		
20	0	39	0	0	0	0	x	x	x	30	28	29	0.7	MA	y	y		
21	48	33	0	0	0	0	e700y	e532	e536	31	29	30	1.6	M	y	0.8y		
22	0	10	0	0	0	0	x	x	y	32	32	32	3.2	y	y	y		
23	0	160	0	0	0	0	x	x	y	y	y	23	1.9	M	y	y		
24	183	169	y	y	0	0	e1,600±	x	x	35	24	28	1.5	M	y	y		
25	0	39	0	0	0	0	e1,400y	e946y	e868	35	32	33	2.6	M	y	1.5		
26	5	5	0	0	0	0	e1,600+	y	y	y	y	28	1.5	M	x	x		
27	267	57	0	0	0	0	e1,400	y	y	38	34	36	1.2	PM	1,100	1.0		
28	66	44	0	0	0	0												
29	1	2	0	0	0	0												
30	103	0	0	0	0	0												
31	29	2	0	0	0	0												
32	46	5	0	0	0	0												
33	10	1	0	0	0	0												
34	12	3	0	0	0	0												
35	17	6	0	0	0	0	e1,500+	y	y	34	30	32	1.5	M	x	x		
36	0	5	0	0	0	0	x	x	x	33	31	32	1	M	x	x		
37	39	13	0	0	0	0	x	x	240±	37	23	31	1.0	PA	1,000	y		
38	0	2	0	0	0	0	x	x	x	24	24	24	0.6	A	x	x		
39	0	48	0	0	0	0	x	x	x	31	29	30	1.3	M	x	x		
40	0	8	0	0	0	0	x	x	x	28	28	28	y	P	x	x		
41	739	78	x	x	x	0	e1,400±	e1,000	e700±	38	31	36	1.2	P M	1,129	1.2		
42	147	10	0	0	0	0												
43	62	0	0	0	0	0												
44	0	2	0	0	0	0												
45	495	18	0	0	0	0												
46	34	48	0	0	0	0												
47	1	0	0	0	0	0												

and the O'Brien or North Ward district and may in time be linked with either or both of these districts. The first wells to be completed in this extension area were completed from the pay between 2500 and 2600 ft. Later wells finding this horizon nonproductive were com-

TABLE 1.—(Continued)

Line Number	Producing Rock						Number of Dry and/ or Near-dry Holes to End of 1936	Deepest Zone Tested to End of 1936		
	Name	Age ¹	Char- acter ²	Poros- ity ³	Net Thick- ness, Average in Feet	Struc- ture ⁴		Name	Depth of Hole, Ft.	
1	Big lime	Pli?	Sh	Por	1	MC	3	Delaware Mt. Pennsylvanian	4,133	
2		Per	D, L	Por	50	MC			5,250	
3	Big Lake lime Ellenberger	Per	S	20	x	AD	10	L Ord	9,562	
4		Per	DL	Por	30	AD		L Ord	9,562	
5		Pen Ord	L	Por	y	D		L Ord	9,562	
6	Big lime	Per	SLS	Por	10	A	1	Per	4,801	
7	Big lime	Per	DL	Por	25	A	7	Per	4,528	
8	Big Lake lime	Per	DL	15	75	A	3	Ord	12,786	
9	1400-ft. Yates sand	Per	S	Por	x	A	4	Ord	10,906	
10	1700-ft. pay	Per	S	22	20	A	3	Ord	10,906	
11	2200-ft. pay	Per	S	Por	x	A	10	Ord	10,906	
12	2500-ft. pay	Per	L	Por	x	A	1	Ord	10,906	
13	3000-ft. pay	Per	DL	Por	x	A	10	Ord	10,906	
14	Big lime	Per	DL	Por	50	A	10	Per	4,220	
15	Big Lake lime	Per	DL	Cav Por	30	A	48	Per	4,610	
16	Big Lake lime	Per	DL	Por	20	M Slight nose AD	6	Per	5,083	
17	Big Lake lime	Per	DL	Por	5			Per		
18	Big Lake lime	Per	DL	Por	5			Per		
19	Delaware	Per	S	Por	7			Delaware sand		
20	Big lime	Per	DL	Por	13	A	4	Ord	8,830	
21	Yates lime	Per	DL	Por Cav	100±			Per		
22	Yates sand	Per	S	Por	15	AL	0	Per	1,852	
23	Toborg sand	Cre	SD	Por	20	AL	2.2	Per	1,400±	
24	Big lime	Per	D	Por	x	A	26y	Per	3,962	
25	Big lime	Per	DL	Cav Por	40	A	3y	Per	4,002	
26	Big lime	Per	DL	Por Cav	x	A	6	Per	3,780	
27	O'Brien sand	Per	LLS	Por	40	AM		Per	4,639	
28	O'Brien sand	Per	S	Por	35	A		Per		
29	Big lime	Per	DL	Por	5			Per		
30	O'Brien sand	Per	S	Por	10	A		Per		
31	O'Brien sand	Per	S	Por	10			Per		
32	Big lime	Per	DL	Por	10±	A		Per		
33	Big lime	Per	DL	Por	5			Per		
34	Big lime	Per	DL	Por	10	A		Per		
35	Big Lake lime	Per	DL	Por	15			Per		
36	Big lime	Per	DL	Por	x	D	2	Mis	3,859	
37	Pecos Valley sand	Per	S	Por	15	A	10	Per	9,967	
38	Yates sand	Per	SH	Por	5	A	7	Per	2,550	
39	Yates sand	Per	DL	Por	15	D	0	Per	2,185	
40		Per	S	Por	6	D	1	Per	2,185	
41	O'Brien sand	Per	S, D	Por	50	ML	3	Per	4,825	
42	O'Brien sand	Per	S	Por	15±	A		Per		
43	Estes sand	Per	S	Por				Per		
44	Shipley-Hazlett	Per	S	Por	6	A		Per		
45	Penn-Bennett	Per	S	Por	30			Per		
46	Shipley-Hazlett, Big lime	Per	S	Por	10	A	T	Per	4,675	
47	Delaware sand	Per	DL S	Por	4	T		Per		

pleted in a second brown sandy lime zone occurring between 2900 and 3000 feet.

Seminole.—As predicted in last year's report, Gaines County saw considerable wildcat activity during 1936, resulting in the discovery of one and possibly two new fields and definitely adding Gaines County to the list of oil-producing counties in West Texas. First oil producer on the Seminole geophysical prospect was the Amerada-Averitt Ohio 1-A, which produced 200 bbl. of 33° gravity oil through 1-in. choke on tubing. The discovery well was drilled to 5054 ft. and plugged back to 5029 ft. The Amerada well is an offset to Walsh and Adams-Averitt Ohio No. 1 which was completed as a junked gasser at 4910 ft. As this discovery was not made until December, there has been no further development, but in view of the geophysical picture, it is thought that Seminole will provide Gaines County with a major oil field. Prior to

TABLE 1.—(Continued)

Line Number	Field, County	Age, Years to End of 1936	Area Proved, Acres				Total Oil Production, Bbl.	
			Oil	Oil and Gas ^a	Gas	Total	To End of 1936	During 1935
48	Irion Co., <i>Irion</i>	7	340	0	0	340	100,910 _y	16,000 _x
49	Masterson, <i>Pecos</i>	7	640	0	0	640	222,392	7,040
50	Deep Rock-Fuhrman, Walker, <i>Andrews</i>	6	2,420	0	0	2,420	988,674	411,930
51	Cowden-North, <i>Ector</i>	6	5,760	0	0	5,760	3,873,178	1,158,316
	Sand Hills, <i>Crane</i>							
52	Permian.....	6	1,500±	0	0	1,500±	141,107	10,361
53	Ordovician.....	1	160	0	0	160	15,106	385
54	Todd Ranch, <i>Crockett</i>	5	360	0	120	480	23,503	8,556
55	Addis (So. Cowden), <i>Ector</i>	4	1,500	0	40	1,540	663,330	224,128
56	Harper, <i>Ector</i>	3	320	0	0	320	93,452	33,469
57	Davidson, <i>Ector</i>	2	160	0	0	160	0 ^s	0
58	Means, <i>Andrews</i>	2	7,640	0	0	7,640	689,011	207,099
59	Scharbauer-Goldsmith, <i>Ector</i>	2	20,000±	0	0	20,000±	492,386	65,019
60	White & Baker, <i>Pecos</i> ^a	2	320	0	640	960	3,069	1,855
61	Parker, <i>Andrews</i>	2	80	0	0	80	25,791	10,366
62	Landreth-Johnson.....	2	160	0	0	160	23,054	12,775
63	Sayre, <i>Winkler</i>	2	8,000	0	0	8,000	2,350,225	444,609
64	Keystone-Walton.....	1	6,000	0	0	6,000	578,558	95,077
65	Cordova-Union (Webb Ray), <i>Upton</i>	1	160	0	0	160	14,959	589
66	Foster, <i>Ector</i>	1	4,660	0	0	4,660	109,323	1,600
67	McKinzie, <i>Pecos</i>	1	160	0	0	160	2,447	1,375
68	Bennett, <i>Yoakum</i>	0	160	0	0	160	9,505	0
69	Henderson, <i>Winkler</i>	0	1,500±	0	0	1,500±	217,466	0
70	Duggan, <i>Cochran</i>	0	160	0	0	160	3,747	0
71	Seminole, <i>Gaines</i>	0	160	0	160	320	1,361	0
72	Netterville, <i>Pecos</i>	0	640	0	0	640	62,542	0
73	Albaugh, <i>Dawson</i>	0	160	0	0	160	x	0
74	Dodson-Duffy, <i>Glasscock</i>	0	160	0	0	160	y	0
75	Landreth-Kirk, <i>Gaines</i>	0	160	0	0	160	500 _y	0

^a All wells plugged and abandoned.

^s No pipe-line outlet.

the completion of the Amerada-Averitt well, Landreth Production Corporation's Kirk No. 1 was completed at 4870 ft. pumping 65 bbl. of fluid, of which 23 per cent was water. This well, which is approximately 10 miles south of the Amerada-Averitt well, is not considered to be a commercial producer from this depth.

Dawson County.—Possible commercial production for Dawson County was indicated in mid-December when Ray Albaugh et al.'s Robinson No. 1 was shut in for storage after pumping at the rate of 4 bbl. per hour of pipe-line oil.

Glasscock County.—A new pool was added in Glasscock County through the completion by Floyd C. Dodson and B. A. Duffy of their J. C. Carter No. 1. The importance of this new field is not known as yet. The discovery well, which is 8 miles southeast of the World-McDowell field, made 110 bbl. of fluid on a pumping test, of which 70 bbl. was oil. Total depth of the discovery well is 2664 ft. after plugging back from 2669 feet.

TABLE 1.—(Continued)

Line Number	Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.					Number of Oil and/or Gas Wells										Depth, Average in Feet	
	During 1936	Daily Average during Nov. 1936	To End of 1936	During 1935	During 1936	Maximum Daily during 1936	Completed to End of 1936	During 1936		At End of 1936								Bottoms of Productive Wells	To Top of Productive Zone
								Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas ^a	Producing Gas Only	Total	Producing				
48	14,368	48	x	x	x	x	16	0	y	0	9	0	0	0	y	1,410	1,400		
49	194,156	660	x	x	x	x	14	7	0	0	14	0	0	0	14	1,400	1,200		
50	389,003	779	y	242y	y	y	19	6	0	0	17	0	0	0	17	4,628	4,348		
51	2,166,279	5,332	15.5y	4.6y	8.6y	y	109	45	0	0	109	0	0	0	109	4,350	4,400		
52	93,093	259	x	x	x	x	12	9	0	0	12	0	0	0	12	4,400	3,000		
53	14,721	33	x	x	x	x	1	0	0	0	1	0	0	0	1	6,450	5,980		
54	3,779	10	x	x	x	x	6	0	1	0	1	0	0	0	1	1,600	1,599		
55	131,324	339	x	x	x	x	15	0	2	1	12	0	0	0	12	4,200	3,900		
56	35,187	259	x	x	x	x	3	0	0	0	3	0	0	0	3	4,338	4,147		
57	0		x	x	x	x	1	0	0	1	0	0	0	0	1	4,500	4,300		
58	459,390	1,007	y	309	y	y	24	11	0	0	22	0	2	24	4,539	4,468			
59	427,367	1,360	x	x	x	x	27	21	0	0	27	0	0	0	27	4,200	4,100		
60	1,123	0 ^b	0	0	0	0	3	0	2	1	0	0	0	0	1	1,700	1,650		
61	13,955	32	x	x	x	x	2	0	0	0	2	0	0	0	2	4,790	4,627		
62	10,279	27	x	x	x	x	1	0	0	0	1	0	0	0	1	4,166	4,100		
63	1,901,238	5,900	x	x	x	x	202	152	0	0	202	0	0	0	202	3,000	2,780		
64	483,481	1,294	x	x	x	x	31	20	0	0	31	0	0	0	31	3,600	3,000		
65	14,370	33	x	x	x	x	2	1	0	0	2	0	0	0	2	2,125	2,060		
66	107,733	422	x	x	x	x	10	9	0	0	10	0	0	0	10	4,310	4,100		
67	1,072	0	x	x	x	x	1	0	0	1	0	0	0	0	1	1,378	1,338		
68	9,505	72	x	x	x	x	1	1	0	0	1	0	0	0	1	5,264	5,088		
69	217,466	1,295	x	x	x	x	43	43	0	0	43	0	0	0	43	3,120	3,035		
70	3,747	51	x	x	x	x	1	1	0	0	1	0	0	0	1	5,068	5,020		
71	1,361	27	x	x	x	x	2	2	0	0	1	0	1	2	5,029	5,022			
72	62,542	300	x	x	x	x	8	8	0	0	8	0	0	0	8	2,300	2,225		
73	x	0	x	x	x	x	1	1	0	0	1	0	0	0	1	5,038	4,970		
74	y	y	x	x	x	x	1	1	0	0	1	0	0	0	1	2,664	2,632		
75	500y ^a	x	x	x	x	x	1	1	0	0	1	0	0	0	1	4,855	4,538		

EXTENSIONS

Extensions were numerous in West Texas during 1936. Winkler County, with 416 completions, was the most active county in the district, and Ward County followed with 338. As a result of these tests, many acres of production were added to the sandy lime belt running slightly west of north and extending across both Ward and Winkler Counties. Numerous extensions were scored in Ector County, including extensions to the North Cowden, Foster, Harper, Penn and Goldsmith pools. In this group, extensions to the Goldsmith area were perhaps the most important in the district. Productive acreage for this major pool is now estimated at 20,000 acres as compared to the 10,000-acre estimate made a year ago. Extensions were also scored in the Means and Fuhrman pools in Andrews County, as well as in the McCamey pool in Upton County.

TABLE 1.—(Continued)

Line Number	Oil Production Methods at End of 1936						Pressure, Lb. per Sq. In. ^a		Character of Oil, Approx. Average during 1936						Character of Gas, Approx. Average during 1936	
	Number of Wells					Injection into Reservoir ^a	Average at End of		Gravity A.P.I. at 60° F.					Base ^a	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.
	Flowing	Pumping	Gas-lift	Air-lift	Miscellaneous		Initial	1935	1936	Maximum	Minimum	Weighted Average	Sulphur, Per Cent			
48	0	9	0	0	0	0	x	x	x	y	y	39	y	y	y	
49	3	11	0	0	0	0	x	x	x	y	y	28	y	M	y	
50	9	8	0	0	0	0	x	x	x	y	y	28.1	y	M	y	
51	97	12	0	0	0	0	e1,640	e1,528	e1,407	34	30	32	1.5	M	1,100y	1.5
52	11	1	0	0	0	0	x	x	x	37	30	34	0.7	M	x	x
53	0	1	0	0	0	0	x	x	x	35	35	35	0	M	x	x
54	0	1	0	0	0	0	x	x	x	19	19	19	1.15	M	1,097	0.15
55	6	6	0	0	0	0	e1,485	e880	y	34	30	32	y	M	y	0.5
56	1	2	0	0	0	0	x	x	y	37	37	37	y	M	y	y
57	0	0	0	0	0	0	x	x	y	29	29	29	y	M	y	y
58	22	0	0	0	0	0	e1,700	e1,680	e1,657	31	31	31	y	M	603	y
59	27	0	0	0	0	0	e2,000+	e2,000+	e2,000+	39	37	38	1.3	M	x	x
60	0	0	0	0	0	0	x	x	x	31	31	31	y	M	x	x
61	0	2	0	0	0	0	x	x	x	30	29	30	y	M	y	y
62	0	1	0	0	0	0	x	500±	y	36.2	35.8	36.0	2.0	M	x	x
63	202	0	0	0	0	0	e1,100	e1,100	1,000y	37	35	36	y	M	x	x
64	31	0	0	0	0	0	e2,000+	e2,000+	e2,000+	38	36	37	1.5	M	y	y
65	0	2	0	0	0	0	x	x	x	y	y	y	y	M	y	y
66	4	6	0	0	0	0	x	x	x	37	35	36	y	M	x	x
67	0	0	0	0	0	0	x	x	x	y	y	28	y	P	x	x
68	1	0	0	0	0	0	x	0	x	y	y	33	y			
69	42	1	0	0	0	0	y	0	y	28.5	25.5	27.5				
70	1	0	0	0	0	0	x	0	y	y	y	32				
71	1	0	0	0	0	0	2,000±	0	y	y	y	24				
72	8	0	0	0	0	0	x	0	y	34	34	34				
73	0	1	0	0	0	0	x	0	x	y	y	31	y	M		
74	0	1	0	0	0	0	x	0	x	y	y	y				
75	1	0	0	0	0	0	x	0	y	y	y	28				

DRILLING AND PRODUCTION ACCOMPLISHMENTS

There was a marked increase in rotary drilling during the year in West Texas, brought about largely by the increased activity in the northern part of the Permian Basin, where the greater depth to the pay and softer formations have been conducive to rotary drilling. Cable tools are still used almost exclusively at Yates, McCamey, etc. Shooting or acid-treating, and often both, continue to be regulation completion practice in most fields in West Texas. The important part played by acid treatment in the development of West Texas fields is well demonstrated in the McCamey district, many of these outside the productive limits of the McCamey pool, as defined during its original development before the use of acid for increasing lime porosity, had been evolved.

Conservation of reservoir energy is one of the most important problems within the realm of the production engineer. During 1936 several

TABLE 1.—(Continued)

Line Number	Producing Rock						Number of Dry and/or Near-dry Holes to End of 1936	Deepest Zone Tested to End of 1936	
	Name	Age ^f	Character ^g	Porosity ^h	Net Thickness, Average in Feet	Structure ⁱ		Name	Depth of Hole, Ft.
48	Yates sand	Per	S	Por	10	M	17	Per	3,511
49	Pecos Valley sand	Per	S	Por	5	M	5	Per	1,675
50	Big lime	Per	D	Por	25 ^y	A	3	Per	5,088
51	Big lime	Per	DS	19.1	30	A	0	Per	4,627
52	Big lime and Tubb pay	Per	D	Por	50	AD	5	Ord	6,450
53	Simpson?	Ord	LS	Por	100±	AD	1	Ord	6,450
54	Big lime	Per	D	Por	10	A	0	Ord	8,041
55	Big lime	Per	DS	16.5	10	DA	3	Per	4,702
56	Big Lake lime	Per	DS	Por	10	A	0	Per	4,338
57	Big lime	Per	DL	Por	30	A	0	Per	4,509
58	Big lime	Per	DL	Cav	20	A	0	Per	4,556
59	Big Lake lime	Per	DL	Por	30	A	2	Per	4,398
60	Big lime	Per	DS	z	10	A	10	Ord	9,811
61	Big lime	Per	DL	Cav	5	A	0	Per	4,804
62	Big lime	Per	DS	Por	30	A	0	Per	4,180
63	Scarborough sand	Per	SS	Por	8-35	AM	0	Per	3,020
64	Yates sand?	Per	LS	Por	30±	AD	3	Per	4,463
	Big Lake lime								
65	Big lime	Per	DL	Por	g	A	0	Per	2,125
66	Big lime	Per	DL	Por	30±	A	0	Per	4,456
67	Yates sand	Per	S	Por	10	T	4	Per	2,800
68	Big lime	Per	DL	Por	5	N	0	Per	5,282
69	Big lime	Per	DL	Por	15	A	2	Per	3,255
70	Big lime	Per	DL	Por	20	z	0	Per	5,098
71	Big lime	Per	DL	Por	10±	A	0	Per	5,060
72	Yates sand?	Per	S	Por	15	A	1	Per	2,459
73	Big lime	Per	DL	Por	z	z	0	Per	5,055
74	Big lime	Per	DL	Por	4	D	2	Per	3,247
75	Big lime	Per	DL	Por	5	A	3	Per	4,900

attempts at gas conservation were made. The Stanolind Oil & Gas Co., in the North Cowden pool, through the use of formation packers was able to bring about large reductions in gas-oil ratios. These wells, for the most part, have been shot and only in wells in which the shot had been confined to the oil pay was it possible to successfully set a packer.

TABLE 2.—*Number of Wells Drilled in West Texas during 1936 and Total to January 1, 1937*

		Wells Drilled during 1936			Total Wells Drilled to 1/1/37		
		Dry	Oil and Gas	Total	Dry	Oil and Gas	Grand Total
1	Andrews.....	0	15	15	14	44	58
2	Borden.....	1	0	1	26	0	26
3	Brewster.....	1	0	1	26	0	26
4	Crane.....	6	69	75	44	412	456
5	Crockett.....	2	5	7	93	63	156
6	Culberson.....	1	0	1	34	0	34
7	Dawson.....	0	0	0	2	0	2
8	Ector.....	6	99	105	47	313	360
9	El Paso.....	1	0	1	5	0	5
10	Gaines.....	3	2	5	12	2	14
11	Garza.....	3	3	6	26	16	42
12	Glasscock.....	7	11	18	72	146	218
13	Howard.....	11	106	117	67	768	835
14	Hudspeth.....	0	0	0	12	0	12
15	Irion.....	2	0	2	63	17	80
16	Jeff Davis.....	1	0	1	7	0	7
17	Loving.....	0	6	6	20	93	113
18	Lynn.....	0	0	0	6	0	6
19	Martin.....	1	0	1	3	0	3
20	Midland.....	0	0	0	9	0	9
21	Mitchell.....	1	1	2	72	136	208
22	Pecos.....	27	127	154	295	842	1137
23	Presidio.....	0	0	0	8	0	8
24	Reagan.....	1	3	4	71	318	389
25	Reeves.....	2	0	2	49	35	84
26	Scurry.....	1	3	4	32	12	44
27	Schleicher.....	1	0	1	12	1	13
28	Sterling.....	0	0	0	39	0	39
29	Sutton.....	0	0	0	11	0	11
30	Terrell.....	0	0	0	17	0	17
31	Terry.....	0	0	0	2	0	2
32	Tom Green.....	2	0	2	62	0	62
33	Upton.....	18	136	154	84	619	703
34	Val Verde.....	0	0	0	20	0	20
35	Ward.....	16	322	338	91	832	923
36	Winkler.....	12	404	416	49	1213	1262
37	Yoakum.....	2	1	3	5	1	6
38	Accumulative grand total.....	129	1313	1442	1507	5883	7390

As a rule the packer alone did not shut off the gas, but by lubricating a mixture of aquagel and fibrotex down the annular space a shutoff was obtained. Records show a reduction in gas-oil ratios from 25,000 cu. ft. per barrel to approximately 1500 cu. ft. per barrel as a result of successful formation packer shutoffs. The Gulf Oil Corporation, in the Keystone field in Winkler County, and The Ohio Oil Co., in the Yates field, have been partly successful at least in cementing off the gas pay before drilling into the oil pay. It was found to be impossible to cement off the entire gas pay at one time, but by cementing several times it has been possible to cement off the entire gas section. In one instance at Yates, a gas

volume in excess of 100,000,000 cu. ft. per day was completely cemented off and the well, upon completion, showed gas at the rate of 22,000,000 cu. ft. per day on a potential test.

Attention is called to the following changes in the 1936 production tables: The Scarborough-Halley pools take in all the sand pools lying between these two pools except the Sayre pool, which was carried as a separate pool in 1935; Cooper-Page pool, in Schleicher County, has been dropped as indications are that for the time being production in that area is not commercial.

ACKNOWLEDGMENTS

For information used in compiling the summary, the authors wish to thank the following contributors: Messrs. B. E. Thompson and G. A. Pool, Gulf Production Co.; G. F. Scott, Shell Petroleum Corporation; R. W. Harrison, Continental Oil Co.; V. C. Malley, Humble Oil and Refining Co.; E. A. Wahlstrom and R. Tesch, Stanolind Oil and Gas Co.; H. W. Pontius, The Ohio Oil Co.; D. S. Googins, The Standard Oil Company of Texas; Addison Young, Landreth Production Co.; E. Kelso, Phillips Petroleum Co.; N. B. Larsh, Sinclair-Prairie Oil Co.; A. P. Loskamp, Barnsdall Oil Co.; Oliver Culberson, Director of Pipe Line Dept., Railroad Commission of Texas, and Preben Oldenburg, Standard Oil Company of Texas.

Oil and Gas Development in Utah, 1936

By E. W. HENDERSON*

(New York Meeting, February, 1937)

OIL and gas development in Utah in 1936 added nothing of importance to the commercial possibilities of the state and consisted principally of efforts to reach objectives in wildcat wells started prior to 1936. Leasing activity on structures having oil and gas possibilities in beds of Pennsylvanian age or older followed announcement by the Standard Oil Company of California that a test of beds of Mississippian age would be made on the San Rafael structure.

DRILLING

Clay Basin, Dagget County.—The Mountain Fuel Supply Co. completed a third well, sec. 16, T. 3 N., R. 24 E., on a flank of this structure. Total developed open flow of the field is approximately 50 million cubic feet and sufficient reserve has been established to warrant construction in 1937 of a pipe line connecting with the Salt Lake City-Ogden line.

San Rafael, Emery County.—The Standard Oil Company of California started a wildcat test in sec. 22, T. 23 S., R. 11 E. Circulation was lost in a water-filled cavity, in dolomitic limestone, below 2185 ft. and the hole conditioned as a water supply for drilling a second test in sec. 27, T. 23 S., R. 11 E. The Carter Oil Co. in 1921 drilled a well in sec. 24, T. 23 S., R. 11 E., which was abandoned at a depth of 3035 ft. after testing at least a part of the Pennsylvanian section.

Cisco, Grand County.—Drilling operations at the Utah Southern Oil Company's test in sec. 33, T. 22 S., R. 22 E., continued throughout the year. Information obtained by means of a seismographic survey of the area indicated that beds of Pennsylvanian age would be found at approximately 2500 ft. The bottom of the hole at 6300 ft. is believed to be in beds of Pennsylvanian age but positive determination has not been made from the drill cuttings.

Green River, Grand County.—Test of Glen Ruby et al., sec. 34, T. 21 S., R. 16 E., was abandoned at 2627 ft. as a dry hole after drilling into Permian Kaibab limestone. Shows of oil and gas were reported and a flow of carbon dioxide gas under low pressure encountered.

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* U. S. Geological Survey, Salt Lake City, Utah.

Seven Mile, Grand County.—The Columbia Crude Corporation test in sec. 12, T. 25 S., R. 20 E., at a depth of 2050 ft. is shutting off water prior to drilling into objective sands of the Pennsylvanian Paradox formation.

Punchbowl, Washington County.—A test by Arrowhead Petroleum Corporation in sec. 1, T. 43 S., R. 15 W., was indefinitely shut down at a depth of 2500 ft. because of mechanical troubles. The company has announced plans for drilling in 1937 a test of the Callville limestone of Pennsylvanian age on an adjoining structure.

TABLE 1.—*Oil and Gas Production in Utah*

Line Number	Field, County	Age, Years to End of 1936	Area Proved, Acres			Total Oil Production, Bbl.				Total Gas Production, Millions Cu. Ft.			
			Oil	Gas	Total	To End of 1936	During 1935	During 1936	Daily Average during Nov. 1936	To End of 1936	During 1935	During 1936	Maximum Daily during 1936
1	Virgin, Washington.....	29	450	0	450	157,xxx	4,xxx	3,xxx	10	0.0	0.0	0.0	0.0
2	San Juan, San Juan.....	27	160	0	160	11,xxx	50	0	0	0.0	0.0	0.0	0.0
3	Farnham, Carbon.....	13 ¹	0	600	600	0	0	0	0	680.6 ²	22.5	36.8	0.3
4	Cisco, Grand.....	12 ³	0	2,000	2,000	0	0	0	0	3,128.0	0.0 ⁴	0.0	0.0
5	Ashley Valley, Uintah.....	11 ³	0	240	240	0	0	0	0	343.8	45.7	51.5	0.3
6	Clay Basin, Daggett.....	9 ⁴	0	2,800	2,800	0	0	0	0	44.8	0.0	44.8	0.3
7	Total.....		610	5,640	6,250	168,xxx	4,xxx	3,xxx	10	4,197.2	68.2	133.1	0.9

¹ Discovered April 1923; began producing April 1931.

² Discovered September 1924; began producing February 1927.

³ Discovered April 1925; began producing September 1929.

⁴ Discovered April 1927; to be connected with Salt Lake City-Ogden pipe line in 1937.

⁵ Includes 500 million cu. ft. estimated to have been wasted while drilling discovery well.

⁶ Shut in since February 1931.

Line Number	Number of Oil and/or Gas Wells							Depth, Average in Feet		Oil Production Methods at End of 1936		Pressure, Lb. per Sq. In. ^d			Character of Oil, Approx. Average during 1936		
	Completed to End of 1936	During 1936		At End of 1936				Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells		Initial	Average at End of		Gravity A.P.I. at 60° F.		
		Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Gas Only	Total Producing			Pumping	Miscellaneous		1935	1936	Maximum	Minimum	Weighted Average
1	53	3	6	15	14	0	14	665 ⁷	663 ⁷	13	1 ⁸	0	0	0	38	24	34
2	9	0	0	1	0	0	0	200	194	1	0	0	0	0	40	39	39
3	2	0	0	0	0	1	1	3,114	3,093	0	0	750	620	600			
4	10	0	2	8	0	8	8	2,174	2,056	0	0	750	325	325			
5	2	0	0	0	0	2	2	1,675	1,665	0	0	580	230	200			
6	3	1	0	3	0	0	0	5,800	5,700	0	0	2,250	2,250	2,250			
7	79	4	8	27	14	11	25			14	1						

⁴ Footnotes to column heads and explanation of symbols are given on page 291.

⁷ 515 to 815 ft., depending on position of well on monoclinical structure.

⁸ Pumping under vacuum.

PRODUCING FIELDS

Carbon County.—At Farnham field, T. 15 S., R. 11 E., the capacity of Carbon Dioxide & Chemical Company's plant was increased to 25 tons daily through installation of additional equipment and improvement in procedure of purifying and processing the carbon dioxide gas. Car-lot shipments were made to various points on the Pacific Coast.

TABLE 1.—(Continued)

Line Number	Character of Oil, Approx. Average during 1936		Character of Gas, Approx. Average during 1936		Producing Rock						Number of Dry and/or Near-dry Holes to End of 1936	Deepest Zone Tested to End of 1936	
	Sulphur Per Cent	Base ^a	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Name	Age ¹	Character ²	Porosity ³	Net Thickness, Average in Feet	Structure ⁴		Name	Depth of Hole, Ft.
1	100	P			Kaibab-Moenkopi Cont. or upper Kaibab	Per or Tri	L	Por	2	MC	75	Per Coconino-Supai	2,195
2	24	M			Goodridge	Pen	S	Por	6	S	116 ^a	Pen Hermosa	3,663
3			CO ₂		Coconino	Per	S	Por	21	AF	1	Per Kaibab	3,235
4			1,080	00	Dakota Morrison	CreL	S	Por	15	D	3	Jur Kayenta	3,045
5			980	00	Morrison	CreL	S	Por	10	AF	3	Jur Nugget	2,720
6			1,100	y	Dakota	CreL	S	18	40	D	0	Jur Sundance	6,790
7											198		

^a Includes assessment holes.

TABLE 2.—Summary of Drilling Operations in Utah

Important Wildcats Drilled in 1936

County	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Remarks
	Sec.	Twp.	Rge.					
	Survey	Lat.	Long.					
1	Emery	27	23 S.	11 E.	1600	Per Coconino	Pen Hermosa	Standard Oil Co.
2	Grand.	33	22 S.	22 E.	6300	Upper Jurassic	Pen Paradox(?)	Utah Southern Oil Co.
3	Grand.	34	21 S.	16 E.	2627	Upper Jurassic	Per Kaibab	Glen Ruby et al.
4	Grand.	12	26 S.	20 E.	2050	Per Rico	Pen Paradox	Columbia Crude Oil Corp.

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1936.....	2	6
Number of oil wells completed during 1936.....	3	0
Number of gas wells completed during 1936.....	1	0
Number of dry holes completed during 1936.....	0	2

Grand County.—At Cisco dome, T. 20 S., R. 20 E., the abandonment work that will result in all wells in this field being plugged and abandoned was started in 1936 and will be completed in 1937.

Washington County.—At Virgin field, T. 41 S., R. 12 W., three shallow wells, average initial production about 8 bbl., were completed within the productive limits of the field. A number of exhausted producing wells were plugged and abandoned.

ACKNOWLEDGMENTS

The writer gratefully acknowledges the information received from and assistance given by Messrs. H. J. Duncan, Supervisor, Oil and Gas Leasing Operations, U. S. Geological Survey; W. T. Nightingale, Geologist, Mountain Fuel Supply Co.; H. F. Davies, Division Manager, Standard Oil Company of California; H. B. Soyster, Chief, Oil and Gas Leasing Operations, U. S. Geological Survey. Permission to publish production data was given by Messrs. J. R. Douglas, Manager, Uintah Gas Co. and A. E. Goodwin, President, Carbon Dioxide & Chemical Company.

Oil and Gas Development in West Virginia during 1936

BY DAVID B. REGER,* MEMBER A.I.M.E.

(New York Meeting, February, 1937)

THE year 1936 in West Virginia was characterized by increased activity in natural gas. The number of actual completions was only slightly increased but many more wells were drilling than at the end of 1935 and there was almost feverish activity in taking new leases. This pronounced revival is partly due to the fact that the extremely cold winter of 1935-1936 showed that additional supplies of gas would be desirable and partly to the hope of finding new pools in the deeper sands. No new pools have actually been found, but the Oriskany sand (L. Dev.) development of Kanawha County, which was already assured by the end of 1935, was greatly extended into wider and richer territory. The Middle Devonian shale (Childres sand), reached incidentally by Oriskany exploration as well as by direct design, has been productive of gas in much wider areas of Boone, Lincoln, Putnam and Kanawha Counties than heretofore known. Routine drilling to the upper sands in defined territory, also, was greatly increased, although not yet much reflected in completions. The supply of marketable gas, however, has been substantially enlarged. In preparation for further exploration there has been an extensive leasing campaign throughout the entire territory where gas seems at all probable, or even possible. Exact figures are lacking, but new leases have certainly been taken on more than 1,000,000 acres. One operator estimates that 500,000 acres have been leased in the Appalachian geosyncline alone between Parkersburg and Charleston. Exploration, both for shallow and deep-sand gas, on some of these new leases is now under way.

There was little activity in oil. No special search for new pools was made and none was found, but the usual routine drilling in old pools occurred.

One major gas pipe-line enterprise was undertaken and completed. Operating technology was much the same as usual. In certain localities repressuring for oil has become a matter of routine, and in others the use of acid in treating small wells in calcareous beds has been continued. Financially, the year has been eventless. Some attempts to buy and

Manuscript received at the office of the Institute Feb. 11, 1937.

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consolidate existing properties have been made but few such changes of ownership have been concluded.

NEW DEVELOPMENT

In 1936 the State issued 832 permits for drilling. A record kept by the writer (Table 5) shows 734 completions, with 141 oil wells, 461 gas wells and 132 dry holes. One trade journal reports 718 completions, and another lists only 599, the latter figure being obviously too low. It is certain that about 100 more wells are drilling than at the end of 1935. The 141 new oil wells supplied 1600 bbl. per day of new production, as compared to 2028 bbl. from 156 wells in 1935. The 461 new gas wells made available 554,119,000 cu. ft. of new gas per day, as compared to 255,485,000 cu. ft. from 417 wells in 1935.

TABLE 1.—*Oil and Gas Territory, Reserves, Production and Wells in West Virginia as of Dec. 31, 1936*

OIL AND GAS TERRITORY AND RESERVES

Held by Leases, Acres (Probable and Improbable Territory)	Probable Territory Not Held by Lease, Acres	Proved and Probable Acres		Reserves	
		Oil	Gas	Oil, Bbl.	Gas, Million Cu. Ft.
5,000,000	250,000	750,000	2 500,000	96 000,000	7,000,000

OIL AND GAS PRODUCTION

Year	Oil, Bbl.	Average Oil per Well Daily, Bbl.	Gas, Millions Cu. Ft.	Average Gas per Well Daily, Cu. Ft.
To end of 1936.....	399,092,000		6,046,312	
During 1935.....	3,903,000		113,160	
During 1936.....	3,832,000	0.56	125,000 ±	26,548

NUMBER OF OIL AND/OR GAS WELLS

Completed to End of 1936, Oil and Gas	Completed during 1936		At End of 1936	
	Oil	Gas	Oil	Gas
61,200 ±	141	461	18,700 ±	12,900 ±

Principal Areas of Activity

In Boone County 50 wells were drilled at widely scattered localities, resulting in 43 gas wells with 17,052,000 cu. ft. of new production. No oil was found and only seven wells were dry. A considerable amount of the new gas is from the Middle Devonian shale.

In Cabell County no oil was found but there were 79 gas wells out of 86 completions, with 131,783,000 cu. ft. of new production. A large

part of this gas came from an extension of the Big Injun sand (L. Mis.) development near Saltrock, McComas district, where 50 wells accounted for 113,143,000 cu. ft. of new production, averaging 2,262,860 cu. ft. per well. To a large extent the other 36 wells of the county had shale gas.

In Calhoun County the drilling was widely scattered, resulting in 11 new oil wells and 34 gas wells, with perhaps average results.

In Clay County 10 wells out of 18 completions had oil, with 143 bbl. of new production. All these were in the old Big Injun sand development of Henry district. Seven other wells had gas.

In Gilmer County 10 wells out of 46 had oil, with 124 bbl. of new production; and 26 wells had gas with 9,076,000 cu. ft. of daily flow.

In Kanawha County the principal activity has been the drilling for gas in the Oriskany sand (L. Dev.), mainly in Elk, Loudon, Malden and Poca districts, as will be hereinafter detailed.

In Lincoln County 39 wells were drilled, two of which were dry and 37 of which had gas, principally in the Berea sand (L. Mis.) and the shale (M. Dev.), with total open flow of 11,712,000 cu. ft. Several of these shale wells are in the vicinity of McCorkle, Washington district. The productive territory also extends into Washington district, Kanawha County, and Scott district, Boone County.

In Logan County seven wells out of eight completions in Logan district made gas, principally in the Big lime (L. Mis.) and Berea sand (L. Mis.), with total open flow of 21,321,000 cu. ft., or an average of 3,047,143 cu. ft. per well. This development appears to fully prove 2000 acres or more of territory that previously has been somewhat doubtful.

In Putnam County several good gas wells have been drilled to the Devonian shale in the vicinity of Nitro, Pocatalico district. A considerable development at this locality appears probable.

Ritchie County led the state with 113 completions, 36 of which were oil wells with 760 bbl. of production, and 39 of which were gas wells with 30,160,000 cu. ft. of open flow. The other 38 wells were dry. The new gas wells are principally in the Salt (basal Pen.), Keener (L. Mis.) and Big Injun sand (L. Mis.), but there were two successful Berea sand (L. Mis.) wells on the Burning Springs anticline in Grant district where this sand has not been extensively prospected. Two Keener sand wells in Grant district had a combined flow of 15,000,000 cubic feet.

In Roane County 11 small oil wells and 45 gas wells were drilled, the combined production of the latter being 59,636,000 cu. ft. Of these, 14 were Salt sand (basal Pen.) wells along the Flat Fork anticline in Harper district, with total flow of 49,092,000 cu. ft., or an average of 3,506,586 cu. ft. per well. The locality was opened and partly proved many years ago, but had been incompletely drilled because of various failures. Its present revival illustrates the desirability of more complete drilling in many similar situations.

In Upshur County, which is on the southeastern edge of the gas fields, 9 gas wells out of 11 completions were successful. Eight of these were small producers in the Benson sand (U. Dev.).

Oriskany Sand Activity

At the end of 1935 the completion of one oil well and 15 gas wells in the Oriskany sand (L. Dev.) in Kanawha County east and southeast of Charleston gave assurance of an interesting and valuable new development. In 1936 there were 54 completions through the Oriskany, 45 of which had Oriskany sand gas with total open flow of 204,395,000 cu. ft., or an average of 4,542,111 cu. ft. per well. One of these wells, in Elk district near Clyde, also had some Oriskany oil. Several of the nine other wells drilled through the Oriskany were commercial producers in the Middle Devonian shale or in higher sands. The Oriskany wells vary in open-flow capacity from 100,000 to 15,000,000 cu. ft. and in rock pressure from 1200 to 1900 pounds.

This development, as now shown by the maps and well records, is partly along the northwestern slope of the Warfield (Chestnut Ridge) anticline, which has a northeast-southwest axis, in Loudon and Malden districts southeast of Charleston; and partly on the axis and western slope of the Milliken anticline, which has a north-south axis, in Elk and Pocahontas districts east and north of Charleston.

The presently productive territory is included within a rectangle of which the extreme length from north to south is 18 miles and the outside width from east to west is about 6 miles. The included territory would contain about 108 sq. miles, or 69,120 acres. Much of this territory is not yet proved, but none of it is definitely condemned. The fully proved area is approximately 11,000 acres. Reliable unit figures on production are not yet available. Estimates vary from 3,500,000 to 5,000,000 cu. ft. or more per acre.

A pronounced peculiarity of this development is that salt water has been found in two or three wells on the axis of the Warfield anticline, and that the wells farthest down the northwestern slope of this anticline, and farthest down the western slope of the Milliken anticline, have the largest volumes and heaviest rock pressures. Such a situation indicates the possibility of an oil pool slightly farther northwest toward the Appalachian geosyncline.

In northern West Virginia, with the exception of Doddridge County, no Oriskany sand tests have been completed or started in 1936, but the discovery of 500,000 cu. ft. of gas in chert slightly above the top of the Oriskany in the Heyn No. 1 well on the Chestnut Ridge anticline in South Union township, Fayette County, Pa., only 10 miles north of the state line, has caused active leasing in Monongalia and Preston Counties. The Heyn well, which showed gas and was near completion in August

1936, is still unfinished, because the uncased hole collapsed when gas was struck and an attempt to clean it out caused deflection of the drill, so that new drilling for several thousand feet has been required. In the meantime, and in spite of the partly closed hole and the fact that the actual Oriskany sand has not yet been reached, the flow of gas continues at the same approximate rate. Several hundred feet of drilling will be required to reach the sand.

Tables 2, 3 and 4 show the present status of Oriskany sand drilling in West Virginia. Table 4 shows what has been done in Kanawha County from the beginning until the end of 1936; Table 2 shows a list of important wildcat wells completed in the state in 1936, most of which penetrated the Oriskany sand, and Table 3 gives a list of wildcat wells throughout the state, drilling as of Jan. 1, 1937, and designed to test the Oriskany sand.

OPERATING AND EXPLORING TECHNOLOGY

The use of hydrochloric acid for treating small or run-down oil and gas wells in calcareous formations has become standard practice in central and southern West Virginia. Many small wells are saved or revived by this method. Heavier shooting of shale gas wells with gelatin is also the rule. Such a shot is generally made with 4000 to 6000 lb. of gelatin and is designed to affect 400 to 600 ft. of strata, regardless of the exact zone or zones where gas has been found. By this method many small wells are made into profitable producers, but the usual increase is about 100 per cent.

Difficulty caused by freezing in producing gas from the Oriskany sand has been largely eliminated by using the Otis removable bottom-hole choke in connection with a mixing valve. Oil and gas separators instead of drips are being used to remove the distillate from this gas.

Repressuring of oil wells with natural gas in the old fields of northern West Virginia is now practiced over considerable areas, with rather good results. The use of air for this purpose has been practically abandoned and water has never been employed.

There has been a considerable increase in geophysical prospecting for the Oriskany sand by the vertical reflection method, both in bold anticlinal structures and in regions of low structural relief. The presence of a thick shale interval of about 2500 ft. between the Berea sand (basal Mis.) and the Corniferous lime (L. Dev.), which immediately overlies the Oriskany, gives rather dependable results where such a condition prevails, as it does in southern West Virginia.

PIPE LINES

The principal accomplishment in pipe-line activity during the year has been the construction of a new auxiliary natural-gas line by Hope Natural Gas Co. This line starts at the John J. Cornwell compressor

TABLE 2.—Important Wildcats Drilled in West Virginia during 1936

No.	County	Magisterial District	Location		Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Initial Production per Day		Tubing Pressure, Lb. per Sq. In.	Remarks
			Lat.	Long.					Oil, Bbl.	Gas, M. Cu. Ft.		
1	Boone	Peytona	1.12 miles N. of 38° 40'	1.0 miles E. of 81° 45'	4714	Pen.-Kanawha	L. Dev.-Oriskany	Owens Libbey-Owens (Broun & Cochran 7-393)	0	0	0	Dry, abandoned.
2	Boone	Washington	1.38 miles N. of 38° 00'	0.53 miles E. of 81° 50'	4566	Pen.-Kanawha	L. Dev.-Oriskany	Pad Fork O. & G. Co. (Cole & Crane, 92)	0	(?)	(?)	Dry in Oriskany, small Berea Gas well.
3	Doddridge	West Union	1.68 miles N. of 39° 15'	3.93 miles E. of 80° 50'	7837	Perm.-Dunkard	Silt.-Niagara	Columbian Carbon Co. (L. Maxwell, 11 P-GW 43)	0	0	0	Dry in Oriskany.
4	Kanawha	Big Sandy	1.61 miles N. of 38° 25'	3.3 miles E. of 81° 25'	5806	Pen.-Conemaugh	L. Dev.-Oriskany	United Carbon Co. (J. A. & M. F. Osborne, 15)	0	(?)	(?)	Salt water in Oriskany; small gas in M. Dev. shale.
5	Kanawha	Loudon	4.0 miles N. of 38° 10'	3.3 miles E. of 81° 35'	4890	Pen.-Kanawha	L. Dev.-Oriskany	Godfrey L. Cabot, Inc. (Marmet Coal Co. 857)	0	0	0	Dry; abandoned.
6	Kanawha	Poca	2.0 miles N. of 38° 30'	0.89 miles E. of 81° 35'	4871	Pen.-Conemaugh	L. Dev.-Oriskany	W. O. Ziebold & W. Va. Gas Corp. (D. A. Griffith, 1)	0	5400	1860	Oriskany sand gas.
7	Kanawha	Poca	4.55 miles N. of 38° 25'	1.90 miles E. of 81° 40'	4850	Pen.-Conemaugh	L. Dev.-Oriskany	United Carbon Co. (G. W. Facemyer, 1)	0	8000		Oriskany sand gas.
8	Lincoln	Washington	3.65 miles N. of 38° 10'	0.72 miles E. of 81° 50'	4552	Pen.-Kanawha	L. Dev.-Oriskany	Harvard Gas Co. (Lincoln Mineral Co., S. F. G-4)	0	184		Dry in Oriskany; gas in M. Dev. shale.
9	Putnam	Pocataloo	1.2 miles N. of 38° 25'	4.5 miles E. of 81° 55'	4429	Pen.-Conemaugh	L. Dev.-Oriskany	Hand & Smith (Nitro Ind. Corp. H. & S-4)	0	(?)	(?)	No Oriskany sand; gas in M. Dev. shale.

In Proven Fields		Wildcats	
145 (est.)		5 (est.)	
0		141	
455		6	
138		3	

Number of wells drilling Dec. 31, 1936.....
 Number of oil wells completed during 1936.....
 Number of gas wells completed during 1936.....
 Number of dry holes completed during 1936.....

TABLE 3.—*Oriskany Sand Wildcats Drilling in West Virginia in January 1937*

No.	County	Magisterial District	Location		Drilled by	Last Reported Depth, Ft.	Remarks
			Lat.	Long.			
1	Calhoun.....	Center	5.2 miles N. of 38° 50'	0.80 miles E. of 81° 10'	Godfrey L. Cabot, Inc. (A. Hardman, 8-869)	4350	
2	Hancock.....	Grant	5.6 miles N. of 40° 30' (approx.)	4.0 miles E. of 80° 40' (approx.)	John T. Galey (Rachel Talbot, 1)	(?)	Starting; no report on depth.
3	Roane.....	Geary	2.58 miles N. of 38° 35'	1.33 miles E. of 81° 10'	Godfrey L. Cabot, Inc. (T. F. Smith, 879)	5794	
4	Wirt.....	Burning Springs	5.48 miles N. of 38° 55'	1.35 miles E. of 81° 20'	Glen W. Roberts (L. R. & J. A. Roberts, 500)	4937	Salt water showing in Oriskany.
5	Wirt.....	Burning Springs	4.57 miles N. of 38° 55'	0.7 miles E. of 81° 15'	Godfrey L. Cabot, Inc. (W. Hoffman, 1-876)	4165	

station, near Clendenin, Kanawha County, and extends northward by way of Lockney, Gilmer County, and Burnt House, Ritchie County, to Hastings, Wetzel County, a total distance of 95 miles. From Cabot Station, Calhoun County, a new 12 $\frac{3}{4}$ -in. feeder line, about 15 miles long, joins the main line at Burnt House. From Hastings the gas is carried into Ohio and Pennsylvania by existing lines. The main line, which was begun in August and completed late in the year, is of 12 $\frac{3}{4}$ -in. outside diameter, with a capacity of about 40,000,000 cu. ft. per day at normal pressure of 300 lb. The pressure may be raised later to increase the carrying capacity of the line. The pipe is of seamless steel and all joints are electrically welded. A new feature of the enterprise is a calcium chloride brine dehydrator installed at the Cornwell station. Here the gas is first compressed and cooled to 60° F. and then passed into the calcium chloride brine, which has been previously chilled by ammonia expansion to 25° F. After this washing process the brine is removed by distillation, leaving the gas practically free of water.

TABLE 4.—*Oriskany Sand Wells, Kanawha County, W. Va.*

Magisterial District	Completed before 1936				Completed in 1936				Grand Total Number of Wells	Number of Wells Drilling in Jan. 1937
	Gas Wells		Dry in Oriskany	Total Number of Wells	Gas Wells		Dry in Oriskany	Total Number of Wells		
	Number of Wells	M. Cu. Ft. of Gas			Number of Wells	M. Cu. ft. of Gas				
Big Sandy.....	0	0	0	0	0	0	1	1	1	4
Cabin Creek.....	0	0	2	2	0	0	0	0	2	0
Charleston.....	0	0	1	1	0	0	0	0	1	0
Elk.....	8	14,219	1	10 ^a	17	92,832	4	21	31	27
Jefferson.....	0	0	1	1	0	0	0	0	1	0
Loudon.....	3	1,903	2	5	4	1,800	2	6	11	0
Malden.....	4	12,395	1	5	15	35,576	2	17	22	10
Poca.....	0	0	0	0	9	74,187	0	9	9	12
Union.....	0	0	0	0	0	0	0	0	0	2 ^b
Washington.....	0	0	0	0	0	0	0	0	0	0
Total.....	15	28,517	8	24	45	204,395	9	54	78	55

^a Includes one oil well completed in 1934 with 158 bbl. daily production.

^b Both shut down.

STATISTICS

A previous paper by Smith¹ shows a subdivision of the state by fields, and a paper by the writer² gives a classification by producing areas.

¹ V. C. Smith: Oil and Gas Production in Kentucky, Ohio and West Virginia. *Trans. A.I.M.E.* (1934) **107**, 229-242.

² D. B. Reger: Oil and Gas Development in West Virginia during 1934. *Trans. A.I.M.E.* (1935) **114**, 457-469.

These subdivisions are somewhat arbitrary and mostly a matter of opinion because of interconnections, and there is no record of production by such boundaries, or even by districts or counties. A repetition of these tables

TABLE 5.—*Summary of New Development in West Virginia during 1936*

County	Wells Drilled	Oil		Gas		Dry Holes
		Number of Wells	Bbl. per Day	Number of Wells	M. Cu. Ft. per Day	
Boone	50	0	0	43	17,052 ^a	7
Braxton	6	1	35	5	1,125 ^a	0
Cabell	86	0	0	79	131,783 ^a	7
Calhoun	57	11	108 ^a	34	22,808 ^a	12
Clay	18	10	143 ^a	7	4,504 ^a	1
Doddridge	8		1	5	385 ^a	3
Fayette	2			2	1,141	
Gilmer	46	10	124 ^a	26	9,076 ^a	10
Hancock	7	7	25			
Harrison	6			6	2,000 ^a	
Jackson	3	3	36			
Kanawha	83	8	42 ^a	64	209,353	11
Lewis	6			3	465	3
Lincoln	39			37	11,712 ^a	2
Logan	8			7	21,321 ^a	1
Marion	14	2	3	9	2,215 ^a	3
Marshall	15	3	34 ^a	11	6,483 ^a	1
Mingo	1			1	81	
Monongalia	11	2	5	7	1,855 ^a	2
Pleasants	28	13	29	3	400	12
Putnam	2			2	?	
Raleigh	2			2	329	
Ritchie	113	36	760 ^a	39	30,169 ^a	38
Roane	45	11	75	22	59,636 ^a	12
Taylor	1			1	?	
Tyler	10	4	28	4	1,200 ^a	2
Upshur	11			9	1,181 ^a	2
Wayne	15	1	25	13	4,008 ^a	1
Wetzel	26	8	81 ^a	16	12,882 ^a	
Wirt	15	5	27	3	655 ^a	
Wood	9	6	19	1	300	2
Total	734	141	1600	461	554,119	132

^a Several wells unknown; assumed same as county average of known wells.

would be of small value. A further paper by the writer³ gives an opinion, or estimate, of oil and gas territory and reserves, and statistics on production and wells as the end of 1935. Table 1 herewith shows this

³ D. B. Reger: Oil and Gas Development in West Virginia during 1935. *Trans. A.I.M.E.* (1936) **118**, 425-432.

information as of the end of 1936. The first section of the table, on oil and gas territory and reserves, represents the judgment of the writer and may not agree with the opinions of others.

The second section, on oil and gas production, may be regarded as fairly accurate, except that no allowance is made for gas that has been lost incidentally to the production of oil and lack of gas markets in the early years of the industry. This loss, which has been very small in the last several years, has been estimated by the writer as 2,750,000 million cubic feet, and if added to the captured production would give a figure of 8,796,312 million cubic feet. During 1936 the extensions of old pools and the assurance of added production in deeper sands have equaled or perhaps slightly exceeded actual production and hence the figure of 7,000,000 million cubic feet as the pipe-line gas reserve of the state is the same as for the end of 1935.

The third section, on number of oil and/or gas wells, is an approximation, based on the best available information.

ACKNOWLEDGMENTS

The writer is glad to acknowledge helpful information and suggestions from the following organizations and individuals: West Virginia Department of Mines, Miss Marie Griffith; West Virginia Geological Survey, Mr. R. C. Tucker; Public Service Commission of West Virginia, Mr. N. R. Henderson; Godfrey L. Cabot, Inc., Mr. Charles Brewer, Jr.; Columbian Carbon Co., Mr. O. W. Van Petten; Commonwealth Gas Corporation, Mr. J. E. Billingsley; Hope Natural Gas Co., Mr. L. L. Tonkin; Huntington-Oklahoma Oil Co., Mr. G. W. Keller; Chas. E. Krebs, Inc., Mr. C. E. Krebs; Owens, Libbey-Owens Gas Department, Mr. R. C. Lafferty; Mr. Veleair C. Smith, Consulting Engineer and Geologist; United Fuel Gas Co., Mr. A. H. McClain.

Oil Development and Production in Wyoming in 1936

BY E. W. KRAMPERT*

THE oil industry was very active in Wyoming in 1936, in contrast to the several quiet years preceding. Production for the year again increased about 7 per cent, following an 8 per cent increase in 1935. During the year, 85 oil wells were completed, compared to 55 in 1935. Three gas wells were completed in 1936, and three in 1935. At the end of the year 45 wells were drilling, as compared to 55 drilling at the end of 1935. Two new oil fields and one new gas field were discovered in Wyoming during the year.

In the year 1936 Wyoming produced 14,475,431 bbl. of oil, a gain of 1,001,081 bbl. over the 1935 figure of 13,474,350. This increase, in the main, was due to the taking of light oil from the newly developed Sundance sand pool at Lance Creek, and from the new fields, Quealy and Medicine Bow, which contributed their first production this year. Most of the other old fields either were partly shut in in competition with the new fields, or showed a normal decline. This was especially noticeable in the black-oil fields, where production had been slowly but steadily increasing for a number of years. During 1936 black-oil production decreased approximately 100,000 bbl. as compared to 1935. The only black-oil field to show marked increase was Garland, which managed to take the market from less favorably located fields. The production of Wyoming in 1936 was 11,358,757 bbl. of light oil and 3,116,674 bbl. of black oil.

Salt Creek, with a production of 6,015,000 bbl., is still the largest single oil-producing field, accounting for 42 per cent of the year's total production. Lance Creek, an old field, with newly developed production in the Sundance sand, reached second place this year for the first time in its history, with a production of 1,878,486 bbl. Lance Creek production will almost equal that of Salt Creek in 1937, if the present rate of production is maintained during the coming year.

Oregon Basin, a large black-oil field, held second place in 1935, but owing to a greatly lessened demand for its production, dropped back to third place in 1936. This was in part due to greatly increased light oil available, and in part to the greater supply of black oil available at

Manuscript received at the office of the Institute March 11, 1937.

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TABLE 1.—*Oil and Gas Production in Wyoming*

Line Number	Field, County	Age, Years to End of 1936	Area Proved, Acres	
			Oil	Oil and Gas ^a
1	Alkali Butte, <i>Fremont</i>	8	40	
2	Allen Lake, <i>Carbon</i>	3	0	0
3	Ant Hills, <i>Niobrara</i>	9	40	0
4	Baxter Basin, <i>Sweetwater</i>		0	
5	Frontier.....	14	0	0
6	Dakota.....	14	0	0
7	Total.....	14	0	0
8	Badger Basin, <i>Park</i>	6	300	0
9	Big Muddy, <i>Converse</i>			
10	Shannon.....	20	2,000	
11	Wall Creek.....	20	2,600	
12	Dakota.....	14	400	
13	Total.....	20	2,600	
14	Big Sand Draw, <i>Fremont</i>			
15	Wall Creek.....	19		
16	Lakota.....	6		
17	Total.....	19		
18	Billy Creek, <i>Johnson</i>	15		
19	Black Mountain, <i>Hot Springs</i>			
20	Embar.....	11	60	
21	Tensleep.....	13	300	
22	Total.....	13	300	
23	Bolton Creek, <i>Natrona</i>			
24	Sundance.....	16	50	
25	Embar.....	16	50	
26	Total.....	16	50	
27	Boone, <i>Natrona</i>	16	0	0
28	Byron, <i>Big Horn</i>			
29	Frontier.....	14		
30	Sundance.....	7	40	
31	Embar-Tensleep.....	4	2,950	
32	Total.....	14	2,950	
33	Circle, <i>Fremont</i>	13	250	0
34	Dallas Derby, <i>Fremont</i>	53	350	0
35	Dutton Creek, <i>Carbon</i>			
36	Shannon.....	10		
37	Dutton Creek, <i>Carbon</i>			
38	Muddy.....	10	150	
39	Total.....	10	150	
40	East Allen Lake, <i>Carbon</i>	0		
41	West Ferris, <i>Carbon</i>			
42	Dakota.....	15		
43	Sundance.....	11		
44	Total.....	15		
45	Eight Mile Lake, <i>Carbon</i>	13		
46	Elk Basin, <i>Park</i>			
47	Frontier.....	21	580	
48	Dakota.....	15		
49	Total.....	21	580	
50	Enos Creek, <i>Hot Springs</i>	13		
51	Ferris, <i>Carbon</i>	19		200
52	Four Bear, <i>Park</i>	8	500	
53	Frannie, <i>Park</i>			
54	Tensleep.....	8	500	
55	Madison.....	7	10	
56	Total.....	8	510	
57	Garland, <i>Big Horn Park</i>			
58	Frontier.....	29	40	0
59	Dakota.....	17		
60	Embar-Tensleep.....	9	160	
61	Madison.....	5	1,500	960
62	Total.....	29	1,500	960

^a Footnotes to column heads and explanation of symbols are given on page 291.

TABLE 1.—(Continued)

Line Number	Area Proved, Acres		Total Oil Production, Bbl.				Total Gas Production, Millions Cu. Ft.			
	Gas	Total	To End of 1936	During 1935	During 1936	Daily Average during Nov. 1936	To End of 1936	During 1935	During 1936	Maxi- mum Daily during 1936
1	300	300	8,130	0	0	0	0	0	0	0
2	200	200					1,504	650 ^a	754	y
3	0	40	7,378	0	0	0				
4										
5	7,467	7,467					5,044	y	y	y
6	4,310	4,310					6,651	y	y	y
7	7,467	7,467					11,695	y	y	y
8	0	300	87,370	12,200	14,820	41				
9										
10		2,000	1,xxx,xxx	x	x	x				
11		2,600	23,xxx,xxx	520,xxx	44x,xxx	x				
12		400	62x,xxx	4x,xxx	70,000	x				
13		2,600	24,771,032	569,000	519,032	1,333				
14										
15	1,200	1,200					42,246 ^a	2,750	3,246	y
16	300	300					0	0	0	0
17	1,200	1,200					42,246 ^a	2,750	3,246	y
18	700	700					2,013	300 ^a	383	y
19										
20	0	60	62,xxx	25,xxx	15,xxx	y				
21	0	300	100,xxx	40,xxx	33,xxx	y				
22	0	300	162,064	65,000	48,564	140				
23										
24		50	3x,xxx	0	0	0				
25		50	1x,xxx	0	0	0				
26		50	45,600	0	0	0				
27	300	300					4,048	60 ^a	18	x
28										
29	500	500					2,876	200 ^a	376	y
30		40	14,000	0	0	0				
31		2,950	775,338	335,000	283,338	0				
32	500	2,590	789,338	335,000	283,338	1,680	2,876	200 ^a	376	y
33	0	250	0	0	0	0				
34	0	350	2,297,075	205,000	215,575	625				
35										
36	800	800					988	200 ^a	163	y
37										
38		150	200,111	27,200	20,211	57				
39	800	800	200,111	27,200	20,211	57	988	200 ^a	163	y
40	160	160					0	0	0	0
41										
42	3,100	3,100					8,030	20 ^a	10	y
43	3,500	3,500					15,959	630 ^a	329	y
44	3,500	3,500					23,989	650 ^a	339	y
45	250	250					4,758	60 ^a	98	y
46										
47		580	10,537,575	106,400	180,575	625				
48	1,200	1,200					20,937	1,550 ^a	1,682	y
49	1,200	1,200	10,537,575	106,400	180,575	625	20,937	1,550 ^a	1,682	y
50	500	500					0	0	0	0
51	200	200	483,924	7,800	7,204	12	y	y	y	y
52		500	0	0	0	0				
53										
54		500	1,858,222	152,750	411,072	1,482				
55		10	82,750	5,250	5,500	15				
56		510	1,940,972	158,000	416,572	1,497				
57										
58	1,000	1,040	342,700	y	2,700	10				
59	1,200	1,200					20,272	125 ^a	147	y
60	1,650	1,650					20,628	450 ^a	18,878 ^a	y
61		1,500	1,746,445	421,400	543,045	2,215		0 ^a		y
62	1,650	1,650	2,089,145	421,400	545,745	2,225	40,900	575 ^a	19,025	y

TABLE 1.—(Continued)

Line Number	Number of Oil and/or Gas Wells							Depth, Average in Feet		Oil Production Methods at End of 1936				Injection into Reservoir ^c	Pressure, Lb. per Sq. In. ^d			Character of Oil, Approx. Average during 1936		
	Completed to End of 1936	During 1936		At End of 1936				Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells			Average at End of		Gravity A.P.I. at 60° F.					
		Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Gas Only	Total Producing			Flowing	Pumping	Gas-lift			1935	1936	Maximum	Minimum	Weighted Average	
1	3	0	0	3	0	0	0	4,600	4,570	0	1	0		y	y	y	x	x	36	
2	3	0	0	0	0	0	3	2,175	2,100					y	y	y	x	x	36	
3	2	0	0	0	0	0	0	3,957	3,951	0	0	0		x	x	x	x	x	36	
4																				
5	12	3	0	0	0	11	11	2,400	2,350					800	760	740				
6	11	0	0	0	0	0	11	3,500	2,500					815	y	760				
7	23	2	0	0	0	22	22													
8	2	1	0	0	2	0	2	8,500	8,250	0	2	0		x	x	x	y	y	48	
9																				
10	35	0	0	25	10	0	10	1,250	1,200	0	10	0	0	x	x	x	y	y	31	
11	134	0	0	0	134	0	134	3,400	3,260	0	134	0	0	x	x	x	y	y	32	
12	5	0	0	0	5	0	5	4,700	4,600	0	5	0	0	x	x	x	y	y	36	
13	174	0	0	25	149	0	149			0	149	0	0							
14																				
15	10	0	0	0	0	10	10	2,800	2,300					1,200	y	y				
16	1	0	0	1	0	0	0	4,350	4,300					1,860	1,860	1,860				
17	11	0	0	1	0	10	10													
18	8	0	0	0	0	8	8	3,250	3,200					1,150	y	y				
19																				
20	2	0	0	0	2	0	2	2,950	2,900	0	2	0	0	x	x	x	y	y	25	
21	4	0	0	0	4	0	4	3,350	3,170	0	4	0	0	x	x	x	y	y	23	
22	6	0	0	0	6	0	6			0	6	0		x	x	x				
23																				
24	3	0	0	3	0	0	0	1,120	1,100	0	3	0		x	x	x	y	y	22	
25	1	0	0	1	0	0	0	2,050	2,025	0	1	0		x	x	x	y	y	32	
26	4	0	0	4	0	0	0			0	4	0								
27	4	0	0	2	0	2	2	2,200	2,150					y	y	y				
28																				
29	2	0	0	0	0	2	2	2,500	2,400					1,000	y	y				
30	1	0	0	1	0	0	0	4,209	4,205		1	0	0	x	x	x	x	x	32	
31	12	7	0	0	12	0	12	5,700	5,300	0	12	0	0	y	x	x	y	y	25	
32	15	7	0	1	12	2	14			0	13	0	0							
33	2	0	0	2	0	0	0	655	170	0	2	0	0	x	x	x	x	x	23	
34	72	0	0	10	42	0	42	1,200	700	0	42	0	0	x	x	x	y	y	23	
35																				
36	5	0	0	0	0	5	5	1,700	1,600					450	y	y				
37																				
38	3	1	0	1	3	0	3	4,900	4,850	0	3	0	0	x	x	x	y	y	34	
39	8	1	0	1	3	5	8			0	3	0	0							
40	1	1	0	0	0	1	1	2,000	2,088					1,020		1,020				
41																				
42	2	0	0	0	0	2	2	2,300	2,200					700	y	y				
43	11	0	0	0	0	11	11	2,700	2,600					1,140	y	y				
44	13	0	0	0	0	13	13													
45	4	0	0	3	0	1	1	3,500	3,400					1,724	y	y				
46																				
47	149	0	0	6	143	0	143	1,200	1,000	0	143	0	0	x	x	x	y	y	43	
48	5	0	0	1	0	4	4	2,500	2,400					925	y	y				
49	154	0	0	7	143	4	147			0	143	0	0							
50	1	0	0	1	0	0	0	2,850	2,600					790	x	x				
51	25	0	0	14	8	3	8	1,650	1,600	0	8	0	0	y	y	y	y	y	36	
52	1	0	0	1	0	0	0	3,350	3,270	0	0	0	0	y	y	y	x	x	15	
53																				
54	13	0	0	2	11	0	11	2,800	2,770	0	11	0	0	x	x	x	y	y	28	
55	1	0	0	0	1	0	1	3,013	3,012	0	1	0	0	x	x	x	y	y	18	
56	14	0	0	2	12	0	12			0	12	0	0							
57																				
58	4	0	0	0	3	1	4	900	700	0	3	0	0	x	x	x	y	y	42	
59	10	0	0	0	0	10	10	1,600	1,500					x	y	y				
60	3	1	0	0	1	2	3	3,200	3,000	0	1	0	0	1,450	y	y				
61	8	3	0	0	8	0	8	4,400	4,000	0	1	0	0	1,600	y	y			19	
62	25	4	0	0	12	13	25			7	5	0	0							

TABLE 1.—(Continued)

Line Number	Character of Oil, Approx. Average during 1936		Character of Gas, Approx. Average during 1936		Producing Rock						Deepest Zone Tested to End of 1936		
	Sulphur, Per Cent	Base ^e	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Name	Age ^f	Character ^g	Porosity ^a	Net Thickness, Average in Feet	Structure ^h	Number of Dry and/or Near-dry Holes to End of 1936	Name	Depth of Hole, Ft.
1	0. y	M	y	y	Morrison	Jur	S	Por	30	A	18	Chugwater	5,460
2			y	y	Sundance	Jur	S	Por	40	A	4	Chugwater	4,083
3	0.1	M			Dakota	CreU	S	Por	6	A	2	Lakota	4,257
4													
5			1,020	y	Frontier	CreU	S	Por	16	AF			
6			760	y	Dakota	CreU	S	Por	50	AF			
7										AF			
8	0. x	P			Frontier	CreU	S	Por	49	A	5	Nugget	3,822
9											0	Frontier	8,725
10	y	M			Shannon	CreU	S	Por	65	A			
11	0.17	M			Wall Creek	CreU	S	Por	100	A			
12	0.18	M			Dakota	CreU	S	Por	15	A			
13										A			
14											226	Madison	6,597
15			1,020	y	Wall Creek	CreU	S	Por	150	A			
16			1,020	x	Lakota	CreU	S	Por	40	A			
17													
18			890	y	Frontier	CreU	SH	Por	20	A	3	Sundance	5,345
20	2.8	A			Embar	Per	L	Cav	35	A	5	Sundance Shale	4,400
21	2.9	A			Tensleep	Pen	S	Por	100	A			
22													
23											2	Madison	3,832
24	2.8	A			Sundance	Jur	S	Por	10	AF			
25	3.0	A			Embar	Per	L	Cav	15	AF			
26													
27			y	y	Shannon	CreU	S	Por	70	A	11	Amsden	2,867
28											1	Niobrara	5,200
29			y	y	Frontier	CreU	S	Por	30	A			
30	0.38	M			Sundance	Jur	S	Por	4	A			
31	2.2	A			Embar-Tensleep	Jur, Per	L-S	Cav-Por	130	A			
32													
33	y	A			Tensleep	Pen	S	Por	50	A	3	Amsden	5,505
34	2.4	A			Embar-Tensleep	Per-Pen	L-S	Cav-Por	150	A	0	Tensleep	650
35											23	Tensleep	1,400
36			y	y	Shannon	CreU	S	Por	40	A			
37													
38	0.3	M			Muddy	CreU	S	Por	30	A			
39													
40			1,022	y	Sundance	Jur	S	Por	48	A	1	Sundance	5,488
41											2	Sundance	2,088
42			1,060	y	Dakota	CreU	S	Por	30	A			
43			1,060	y	Sundance	Jur	S	Por	110	A			
44													
45			1,069	y	Dakota	CreU	S	Por	50	A	1	Tensleep	4,690
46											4	Chugwater	4,560
47	0.14	P			Frontier	CreU	S	Por	40	AF			
48			y	y	Dakota	CreU	S	Por	55	AF			
49													
50			x	x	Frontier	CreU	S	Por	40	A	39	Dakota	2,450
51	0.45	M	1,060	y	Mowry-Dakota	CreU	S	Por	25	A	0	Dakota	3,992
52	3.88	A			Tensleep	Pen	S	Por	60	A	8	Embar	4,600
53											1	Tensleep	3,350
54	2.5	A			Tensleep	Pen	S	Por	100	AF			
55	3.3	A			Madison	Mis	L	Cav	x	AF			
56													
57											4	Madison	3,230
58	y	P	y	y	Frontier	CreU	S	Por	35	AF			
59			y	y	Dakota	CreU	S	Por	50	AF			
60			y	y	Embar-Tensleep	Per-Pen	L-S	Cav-Por	100	A			
61	3.0	A	y	y	Madison	Mis	L	Cav	320	A			
62											83	Madison	4,424

TABLE 1.—(Continued)

Line Number	Field, County	Age, Years to End of 1936	Area Proved, Acres	
			Oil	Oil and Gas ^a
63	Golden Eagle, <i>Hot Springs</i>	17	0	0
64	Grass Creek, <i>Hot Springs</i>			
65	Frontier.....	22	1,400	0
66	Embar-Tensleep.....	15	2,000	0
67	Total.....	22	2,000	0
68	Greybull, <i>Big Horn</i>	28	640	
69	Hamilton, <i>Hot Springs</i>			
70	Embar.....	18	640	
71	Tensleep.....	7	300	
72	Total.....	18	640	
73	Hidden Dome, <i>Washakie</i>	19	200	0
74	La Barge, <i>Lincoln, Sublette</i>	13	950	
75	Lake Creek, <i>Hot Springs</i>	11	100	
76	Lance Creek, <i>Niabrara</i>			
77	Dakota.....	14	0	1,500
78	Sundance.....	6	1,100	
79	Total.....	14	1,100	1,500
80	Lander (Hudson), <i>Fremont</i>			
81	Embar.....	18	340	
82	Tensleep.....	10	110	
83	Total.....	18	340	
84	Little Buffalo Basin, <i>Park</i>	22		
85	Little Grass Creek, <i>Hot Springs</i>	20		
86	Little Pole Cat, <i>Park</i>	18		
87	Lost Soldier, <i>Sweetwater</i>			
88	Frontier.....	20	160	
89	Dakota-Lakota.....	14	450	
90	Sundance.....	10	160	
91	Tensleep.....	6	160	
92	Total.....	20	450	
93	Mahoney Dome, <i>Carbon</i>			
94	Dakota.....	17		
95	Sundance.....	12		
96	Tensleep.....	7	200	
97	Total.....	16	200	
98	Maverick Spgs., <i>Fremont Co.</i>	19	1,400	
99	Medicine Bow, <i>Carbon</i>	2		800
100	Midway, <i>Natrona</i>	6	200	
101	Mule Creek, <i>Niabrara</i>			
102	Lakota.....	16	220	
103	Minnelusa.....	6	100	
104	Total.....	16	220	
105	Muskrat, <i>Fremont</i>	9	200	
106	North Baxter, <i>Sweetwater</i>			
107	Dakota.....	10		
108	Sundance.....	8		
109	Total.....	10		
110	North Garland, Danker Domes, <i>Big Horn</i>	21		
111	North Casper Creek, <i>Natrona</i>	5	100	
112	North Sunshine, <i>Park</i>	9	150	
113	Notches, <i>Natrona</i>	14	400	
114	Oregon Basin, <i>Park</i>			
115	Dakota.....	24		
116	Embar-Tensleep.....	10	10,000	
117	Total.....	24	10,000	
118	Osage, <i>Western</i>	16	10,000	
119	Pilot Butte, <i>Fremont</i>			
120	Niabrara.....	20	250	
121	Muddy.....	7		
122	Total.....	20	250	
123	Pine Mountain, <i>Natrona</i>	17		
124	Pitchfork, <i>Park</i>	6	300	
125	Plunkett, <i>Fremont</i>	15	45	

TABLE 1.—(Continued)

Line Number	Area Proved, Acres		Total Oil Production, Bbl.				Total Gas Production, Millions Cu. Ft.			
	Gas	Total	To End of 1936	During 1935	During 1936	Daily Average during Nov. 1936	To End of 1936	During 1935	During 1936	Maxi- mum Daily during 1936
63	120	120					2,250	0	0	0
64										
65	0	1,400	23,855,585	509,500	552,085	1,966				
66	0	2,000	1,496,017	210,500	1,517	0				
67	0	2,000	25,351,602	720,000	553,602	1,966				
68		640	245,150	450	0	0	x	x	x	x
69										
70		640	4,126,911	421,000	368,911	900				
71		300	0	0	0	0				
72		640	4,126,911	421,000	368,911	900				
73	640	840	113,613	20,000	83,613	485	24,000	0	0	0
74		950	4,729,436	450,000	428,436	1,100				
75		100	0	0	0	0				
76										
77	0	1,500	4,349,000	50,000	35,000	100	59,800	900 ^a	900	y
78	0	1,100	2,513,486	599,000	1,843,486	7,000	2,962	2,000 ^a	962	y
79	0	1,500	6,862,486	649,000	1,878,486	7,100	62,762	2,900 ^a	1,862	y
80										
81		340	678,231	15,000	13,231	47				
82		110	1,077,885	98,000	95,885	50				
83		340	1,756,116	113,000	109,116	250				
84	4,800	4,800					14,451	1,050 ^a	1,301	y
85	160	160					1,334	135 ^a	99	y
86	500	500					669	125 ^a	144	y
87										
88		160	2,054,038	100,000	54,038	100				
89		450	11,389,294	93,500	122,794	200				
90		160	4,488,334	355,000	288,334	725				
91		160	506,000	6,000	0	0				
92		450	18,437,666	554,500	465,166	1,025				
93										
94	1,400	1,400					14,400	100 ^a	100	y
95	1,660	1,660					42,039	650 ^a	1,189	y
96		200	0	0	0	0				
97	1,660	1,660	0	0	0	0	56,439	750 ^a	1,289	y
98		1,400	0	0	0	0				
99		800	184,920	0	184,920	2,665	285	0	285	y
100		200	165,468	22,800	14,668	30				
101										
102		220	1,200,826	7,000	6,826	0				
103		100	3,750	2,000	0	0				
104		220	1,204,576	9,000	6,826	0				
105	500	500	0	0	0	0	3,483	400 ^a	758	y
106										
107	1,280	1,280					6,017	y	y	y
108	2,368	2,368					4,012	y	y	y
109	2,368	2,368					10,029	2,000 ^a	y	y
110	800	800					21	4	9	y
111		100	1,874	0	0	0				
112		150	0	0	0	0				
113		400	170,000	0	0	0				
114										
115	1,300	1,300					1,494	140 ^a	229	y
116		10,000	7,181,041	1,163,000	915,041	2,200				
117	1,300	10,000	7,181,041	1,163,000	915,041	2,200	1,494	140 ^a	229	y
118		10,000	3,659,274	250,000	267,274	650				
119										
120		250	531,189	9,800	9,189	21				
121	400	400				0	0	0	0	0
122	400	400	531,189	9,800	9,189	21	0	0	0	0
123	100	100					0	0	0	0
124		300	0	0	0	0				
125		45	11,700	0	0	0				

TABLE 1.—(Continued)

Line Number	Number of Oil and/or Gas Wells							Depth, Average in Feet	Oil Production Methods at End of 1936	Pressure, Lb. per Sq. In. ^d	Character of Oil, Approx. Average dur- ing 1936												
	Completed to End of 1936	During 1936		At End of 1936							Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells			Average at End of	Gravity A.P.I. at 60° F.						
		Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Gas Only	Total Producing						Flowing	Pumping	Gas-lift		Injection into Reservoir ^e	Initial	1935	1936	Maximum	Minimum	Weighted Average
63	3	0	0	0	0	0	0	3,000	2,250				1,175	Exhausted									
64																							
65	316	0	0	1	315	0	315	1,200	800	0	315	0	0	x	x	x	y	y	44				
66	15	3	0	0	15	0	15	4,000	3,600	0	15	0	0	x	x	x	y	y	23				
67	331	3	0	1	330	0	330			0	330	0	0	0	0	0							
68	14	0	0	14	0	0	0	1,050	1,000	0	0	0	0	x	x	x	y	y	48				
69																							
70	31	0	0	0	31	0	31	2,600	2,300	0	31	0	0	x	x	x	26	18	23				
71	1	0	0	1	0	0	0	2,860	2,700	0	0	0	0	x	x	x	y	y	21				
72	32	0	0	1	31	0	31			0	31	0	0										
73	20	11	3	4	11	0	11	1,600	1,200	0	11	0	0	490	Exhausted			y	43				
74	110	3	1	19	91	0	91	1,000	650	0	91	0	0	x	x	y	45	19	28				
75	1	0	0	1	0	0	0	3,760	3,730	0	1	0	0	x	x	x	x	x	26				
76																							
77	14	0	0	0	0	4	6	3,200	2,900	0	4	0	0	1,175	y	y	y	y	42				
68	25	26	1	0	25	0	25	4,000	3,650	23	2	0	0	1,200	y	y	49	41	48				
79	39	26	1	0	29	6	35			23	6	0	0										
80																							
81	31	0	0	25	6	0	6	1,500	1,300	0	6	0	0	x	x	x	y	y	21				
82	5	0	0	0	5	0	5	1,800	1,700	0	5	0	0	x	x	x	y	y	23				
83	36	0	0	25	13	0	11			0	13	0	0										
84	10	0	0	2	0	8	8	1,500	1,200				445	y	y								
85	2	0	0	1	0	1	1	2,700	2,650				850	y	y								
86	1	0	0	1	0	0	0	4,100	3,900				1,425	y	1,200								
87																							
88	45	0	0	15	30	0	30	600	300	0	30	0	3	x	x	x	y	y	32				
89	27	0	0	3	24	0	24	1,700	1,500	0	24	0	0	x	x	x	y	y	32				
90	5	0	0	0	5	0	5	2,150	1,950	0	3	2	0	x	x	x	y	y	32				
91	1	0	0	0	1	0	1	4,000	3,900	1	0	0	0	x	x	x	y	y	35				
92	78	0	0	18	60	0	60			1	57	2	3										
93																							
94	4	0	0	0	0	4	4	2,300	2,200				1,060	x	x								
95	9	0	0	0	0	9	9	2,700	2,600				1,170	x	x	x							
96	1	0	0	1	0	0	0	4,760	4,600	1	0	0	0	x	x	x	x	x	34				
97	14	0	0	1	0	13	13			1													
88	32	0	0	32	0	0	0	1,700	1,450	0	0	0	0	x	x	x	y	y	22				
99	5	3	0	0	0	5	5	5,450	5,200	5	0	0	0	2,500	x	x	x	x	63				
100	3	0	0	2	1	0	1	5,250	5,200	0	1	0	0	x	x	x	x	x	32				
101																							
102	37	1	1	37	0	0	0	1,550	1,500	0	0	0	0	x	x	x	x	x	32				
103	1	0	0	1	0	0	0	3,180	3,170	0	0	0	0	x	x	x	x	x	32				
104	38	0	0	38	0	0	0			0	0	0	0										
105	2	1	0	0	1	1	2	4,400	4,350				1,450	y		y							
106																							
107	3	0	0	0	0	3	3	3,100	2,950				1,335	y	1,150								
108	2	0	0	0	0	2	2	3,400	3,350				1,485	1,260	1,190								
109	5	0	0	0	0	5	5																
110	4	0	0	3	0	1	1	2,400	2,200				400	y	y								
111	2	0	0	2	0	0	0	3,210	3,200	0	0	0	0	x	x	x	x	x	23				
112	1	0	0	1	0	0	0	3,700	3,475	0	0	0	0	x	x	x	x	x	16				
113	3	0	0	3	0	0	0	2,850	2,800	0	0	0	0	x	x	x	x	x	23				
114																							
115	4	0	0	0	0	4	4	1,550	1,500				700	y	y								
116	35	0	0	2	33	0	33	3,900	3,500	0	33	0	0	x	x	x	y	y	21				
117	39	0	0	2	35	4	37			0	33	0	0										
118	420	15	6	58	352	0	352	1,525	1,500	0	352	0	0	x	x	x	y	y	41				
119																							
120	13	1	0	0	13	0	13	1,000	800	0	13	0	0	x	x	x	y	y	36				
121	2	0	0	2	0	0	0	3,370	3,350				800	x	x								
122	15	1	0	2	13	0	13			0	13	0	0										
123	2	0	0	2	0	0	0	1,840	1,830	0	0	0	0	700	x	x	x	x					
124	1	0	0	1	0	0	0	3,950	3,750	0	0	0	0	x	x	x	x	x	18				
125	15	0	0	0	0	0	0	500	250	0	0	0	0	x	x	x	x	x	42				

TABLE 1.—(Continued)

Line Number	Character of Oil, Approx. Average during 1936		Character of Gas, Approx. Average during 1936		Producing Rock						Deepest Zone Tested to End of 1936		
	Sulphur, Per Cent	Base ^a	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Name	Age ^b	Character ^c	Porosity ^d	Net Thickness, Average in Feet	Structure ^e	Number of Dry and/or Near-dry Holes to End of 1936	Name	Depth of Hole, Ft.
63					Mesaverde	CreU	S	Por	50	A	5	Cody	4,019
64													
65	0.14	P			Frontier	CreU	S	Por	200	A			
66	2.6	A			Embar-Tensleep	Per-Pen	L-S	Cav-Por	200	A			
67													
68	0.0	P			Greybull	CreU	S	Por	20	MC	85	Amsden	4,336
69											115	Tensleep	2,950
70	2.3	A			Embar	Per	L	Cav	50	Af			
71	3.0	A			Tensleep	Pen	S	Por	60	Af			
72										Af			
73	y	P			Frontier	CreU	S	Por	12	A	2	Tensleep	2,886
74	0.18	M			Wasatch	Eoc	S	Por	150	A	20	Morrison	2,785
75	3.2	A			Embar	Per	L	Cav	30	A	53	Hilliard	4,210
76											2	Tensleep	3,830
77	0.14	P			Dakota	CreU	S	Por	65	A			
78	0.14	P			Sundance	Jur	S	Por	65	A			
79													
80											57	Tensleep	4,450
81	2.3	A			Embar	Per	L	Cav	60	A			
82	2.9	A			Tensleep	Pen	S	Por	125	A			
83													
84			1,000	y	Frontier	CreU	S	Por	100	A	8	Tensleep	2,190
85			y	y	Frontier	CreU	S	Por	50	A	4	Mowry	1,670
86			y	y	Frontier	CreU	S	Por	15	A	0	Frontier	2,915
87											0	Frontier	4,420
88	0.15	M			Frontier	CreU	S	Por	200	A			
89	0.15	M			Dakota-Lakota	CreU	S	Por	80	A			
90	0.15	M			Sundance	Jur	S	Por	300	A			
91	1.4	M			Tensleep	Pen	S	Por	65	A			
92											37	Tensleep	4,009
93													
94			1,140	y	Dakota	CreU	S	Por	30	A			
95			1,140	y	Sundance	Jur	S	Por	110	A			
96	1.3	M			Tensleep	Pen	S	Por	160	A			
97													
98	2.9	A			Embar	Pen	L	Cav	50	A	6	Tensleep	4,690
99	y	P			Sundance	Jur	S	Por	140	A	3	Tensleep	2,094
100	0.3	M			Wall Creek	CreU	S	Por	30	A	6	Chugwater	5,910
101											4	Chugwater	6,689
102	0.17	M			Lakota	CreL	S	Por	25	A			
103	2.4	A			Minnelusa	Pen	L	Cav	10	A			
104											11	Minnelusa	3,185
105					Frontier	CreU	S	Por	35	AF	1	Embar	7,300
106													
107			1,000	y	Dakota	CreU	S	Por	20	AF			
108			935	y	Sundance	Jur	S	Por	15	AF			
109													
110					Frontier	CreU	S	Por	30	AF	5	Sundance	3,800
111	y	A			Tensleep	Pen	S	Por	5	A	1	Frontier	2,800
112	3.9	A			Tensleep	Pen	S	Por	60	A	2	Tensleep	3,308
113	1.7	A			Tensleep	Pen	S	Por	40	A	1	Tensleep	3,712
114					Tensleep	Pen	S	Por	40	A	4	Tensleep	2,830
115													
116	3.3	A			Dakota	CreU	S	Por	35	A			
117					Embar-Tensleep	Per-Pen	L-S	Cav-Por	150	A			
118	0.10	P											
119					Newcastle	CreU	S	Por	10	ML	8	Madison	4,160
120	0.1	P									464	Minnelusa	2,150
121													
122					Niobrara	CreU	H	Fis	x	A			
123					Muddy	CreU	S	Por	18	A			
124	3.87	A			Tensleep	Pen	S	Por	25	A	45	Sundance	4,630
125	0.19	P			Tensleep	Pen	S	Por	40	A	13	Deadwood	3,127
					Mowry	CreU	H	Fis	x	A	0	Tensleep	3,903
											18	Embar	2,500

Garland and Frannie, which are more favorably situated to the black-oil market.

New production from the recently developed Sundance sand at Rock Creek made it possible for this old field to take fourth place this year, though, to a large extent, the output of this field has always been confined to market demand. The new Quealy field and the important new Medicine Bow field are both in the same district, and in the future will share in the market demand created for the Rock Creek field. The additional reserves of the new fields have already resulted in refinery extensions and consequently have increased the market.

Grass Creek, which held third place in 1935, dropped back to fifth place in 1936, because it found no market for black oil during the year. The light-oil production showed a slight increase over last year.

TABLE 1.—(Continued)

Line Number	Field, County	Age, Years to End of 1936	Area Proved, Acres	
			Oil	Oil and Gas ^a
126	Poison Spider, <i>Natrona</i>	18		400
127	Powder River, <i>Natrona</i>	6		
128	Quealy, <i>Albany</i>	3	160	
129	Rex Lake, <i>Albany</i>	13	200	
130	Rock Creek, <i>Carbon</i>			
131	Dakota.....	19	1,300	
132	Sundance.....	2	180	
133	Total.....	19	1,300	
134	Salt Creek, <i>Natrona</i>			
135	1st Wall Creek.....	28	4,350	
136	2nd Wall Creek.....	19	21,450	
137	Lakota.....	12	2,030	
138	Sundance.....	11	660	
139	Tensleep.....	6	640	
140	Total.....	28	21,450	
141	Shannon, <i>Natrona</i>	47	200	
142	Sheep Creek, <i>Fremont</i>	2	200	
143	Simpson Ridge, <i>Carbon</i>	12	160	
144	South Casper Creek, <i>Natrona</i>	14	240	
145	South Sunshine, <i>Park</i>	10	300	
146	Spindletop, <i>Natrona</i>	8	80	
147	Spring Creek, <i>Park</i>	7	750	
148	Spring Valley, <i>Uinta</i>	36	400	
149	Teapot Dome, <i>Natrona</i>			
150	Wall Creek.....	14	640	2,000
151	Shale Total.....	14	<i>x</i>	
152	Total.....	14	640	2,000
153	Torchlight, <i>Big Horn</i>	21	600	
154	Warm Springs, <i>Hot Springs</i>	19	200	
155	Waugh Dome, <i>Hot Springs</i>	3	100	
156	Wertz Dome, <i>Carbon</i>			
157	Frontier.....	11		
158	Dakota.....	16		
159	Lakota.....	9		
160	Sundance.....	7		
161	Tensleep.....	0	250	
162	Total.....	16	250	
163	Total Wyoming.....		67,435	5,660

Because of newly completed flowing wells and favorable position, Garland was able to take market from older black-oil fields sufficient to put it in sixth place in 1936.

Big Muddy and Lost Soldier maintained their usual position, showing only a slightly normal decline. The Frannie field, which held third place in 1934, has dropped back to ninth place in 1936, mainly because of market conditions for black oil.

Gas production during 1936 more than doubled that of 1935, owing to increased market. Only three new gas wells were drilled during the year and one of these is the discovery well on the new East Allen Lake gas field.

In the Garland field a well drilling for oil blew out while penetrating the gas horizons: the Embar, Tensleep, and Madison. The blowout occurred on Jan. 19, 1935 and defied all efforts to kill it until Feb. 28,

TABLE 1.—(Continued)

Line Number	Area Proved, Acres		Total Oil Production, Bbl.				Total Gas Production, Millions Cu. Ft.			
	Gas	Total	To End of 1936	During 1935	During 1936	Daily Average during Nov. 1936	To End of 1936	During 1935	During 1936	Maxi- mum Daily during 1936
126	150	400	745,411	55,000	75,411	270	5,600			
127		150					0	0	0	0
128		160	86,714	0	86,714	360				
129		200	217,260	3,000	1,060	0				
130										
131		1,300	16,421,441	514,000	467,441	y				
132		180	169,000	30,000	139,000	y				
133		1,300	16,590,441	544,000	606,441	1,230				
134										
135		4,350	46,798,900	305,000	293,900	800				
136		21,450	202,762,700	4,858,000	4,604,700	12,800				
137		2,030	15,846,500	685,000	661,500	1,830				
138		660	8,516,900	502,000	454,900	1,250				
139		640	65,000	0	0	0				
140		21,450	271,015,000	6,350,000	6,015,000	16,680				
141		200	55,400	0	0	0				
142		200	10,000	10,000	0	0				
143		160	163,050	0	4,050	11				
144		240	2,240,519	78,600	105,869	500	11,292	0	0	0
145		300	0	0	0	0				
146		80	0	0	0	0				
147		750	0	0	0	0				
148		400	57,500	3,000	3,000	10				
149										
150		2,640	3,000,000	0	0	0	x	0	0	0
151		x	694,287	8,200	7,287	23				
152		2,640	3,694,287	8,200	7,287	23	x	0	0	0
153		600	96,000	0	0	0				
154		200	275,668	41,000	18,518	0				
155		100	106,197	92,000	14,197	120				
156										
157	100	100					700	0	0	0
158	500	500					34,000	500 ^a	500	y
159	500	500					24,494	1,900 ^a	2,094	y
160	200	200					1,600	200 ^a	200	y
161		250	1,000	0	1,000	0				
162	500	500	1,000	0	1,000	0	60,794	2,600	2,794	y
163	33,565	98,590	413,467,183	13,474,350	14,475,431	45,831	410,857	19,900	38,778	y

1936, when it was finally shut in. This well is estimated to have wasted 18 billion cubic feet of gas during 1936. In Table 1, this amount of gas is credited to the production of gas from the Garland field during the year.

DISCOVERIES

East Allen Lake gas field must be listed as a new discovery for 1936, because it is a separate high on the Allen Lake anticline. Gas was discovered on the main or north dome in the Sundance sand in 1934, but there is a definite and rather deep saddle separating the north dome from the east dome and there are several dry holes between them. The East Allen field should no longer be considered an extension of the main Allen Lake field.

TABLE 1.—(Continued)

Line Number	Number of Oil and/or Gas Wells							Depth, Average in Feet		Oil Production Methods at End of 1936				Pressure, Lb. per Sq. In. ^d			Character of Oil, Approx. Average during 1936		
	Completed to End of 1936	During 1936		At End of 1936				Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells			Injection into Reservoir ^e	Initial	Average at End of		Gravity A.P.I. at 60° F.		
		Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Gas Only	Total Producing			Flowing	Pumping	Gas-lift			1935	1936	Maximum	Minimum	Weighted Average
126	18	1	0	5	13	0	13	1,425	1,400	0	13	0	0	525	x	x	y	y	22
127	1	0	0	1	0	0	0	1,350	1,315					530	y	y	y	y	36
128	6	4	1	0	5	0	5	3,320	3,260	0	5	0	0	y	x	x	y	y	35
129	4	0	0	4	0	0	0	3,900	3,800	0	4	0	0	x	x	x	y	y	34
130																			
131	62	0	0	19	43	0	43	2,800	2,600	0	43	0	0	x	x	x	y	y	35
132	9	6	0	0	9	0	9	3,250	3,150	0	9	0	0	x	x	x	y	y	33
133	71	6	0	17	52	0	52			0	52	0	0						
134																			
135	347	0	15	207	140	0	140	1,100	1,000	0	140	0	y	x	x	x	y	y	36
136	1,560	0	0	417	1,143	0	1,143	1,575	1,535	0	1,143	0	y	x	x	x	y	y	36
137	63	0	0	20	43	0	43	2,350	2,300	0	43	0	0	x	x	x	y	y	35
138	44	0	0	9	35	0	35	2,875	2,750	19	16	0	0	x	x	x	y	y	35
139	1	0	0	1	0	0	0	3,980	3,790	0	0	0	0	x	x	x	x	x	28
140	2,015	0	15	654	1,361	0	1,361			19	1,342	0	0						
141	18	0	0	0	0	0	0	900	800	0	0	0	0	x	x	x	x	x	24
142	2	0	0	2	0	0	0	2,100	2,035	0	2	0	0	x	x	x	x	x	24
143	3	3	0	0	3	0	3	675	625	0	3	0	0	x	x	x	y	y	21
144	17	0	0	0	17	0	17	2,700	2,600	0	17	0	0	x	x	x	y	y	15
145	1	0	0	1	0	0	0	2,514	2,475	0	0	0	0	x	x	x	x	x	18
146	3	0	0	3	0	0	0	1,125	1,100	0	0	0	0	x	x	x	x	x	22
147	1	0	0	1	0	0	0	4,250	3,900	0	0	0	0	x	x	x	x	x	16
148	30	2	2	20	10	0	10	900	400	0	10	0		x	x	x	x	x	38
149																			
150	47	0	0	47	0	0	0	2,950	2,900	0	0	0	0	x	x	x	x	x	35
151	15	0	0	15	2	0	2	1,600	1,200	0	2	0	0	x	x	x	y	y	35
152	62	0	0	60	2	0	2			0	2	0	0						
153	30	0	0	30	0	0	0	600	400	0	0	0	0	x	x	x	x	x	46
154	37	0	0	37	0	0	0	800	700	0	0	0	0	x	x	x	x	x	21
155	1	1	1	0	1	0	1	3,807	3,775	0	1	0		x	x	x	x	x	28
156																			
157	0	0	0	0	0	0	0	2,260	2,210					850	y	y			
158	3	0	0	0	0	3	3	3,550	3,500					1,940	y	y			
159	3	0	0	0	0	3	3	3,750	3,700					1,940	y	y			
160	1	0	0	0	0	1	1	4,120	4,100					1,520	y	y			
161	1	1	0	0	0	0	0	5,886	5,859	1	1			x	y	y	y	y	35
162	8	1	0	0	1	7	8												
163	4,191	83	30	1,146	2,819	134	2,951			57	2,780	2	y						

In 1935 the Sinclair Wyoming Oil Co. started a dual-purpose well on the Wertz dome, in Carbon County. Wertz dome is an old, developed gas field with only one gas well to the Sundance sand, and this well has always given some water trouble. The purpose of the new well was to penetrate the Sundance sand and test out water conditions in the sand. This well was completed as a gas well in the Sundance sand at the end of 1935 and allowed to produce gas from this sand until it was finally learned that the water troubles were inherent, and not due to mechanical difficulties in the previous well. In the summer of 1936, therefore, the test well was rigged up for deepening and to serve its other purpose, which was to test the Tensleep sand.

TABLE 1.—(Continued)

Line Number	Character of Oil, Approx. Average during 1936		Character of Gas, Approx. Average during 1936		Producing Rock						Number of Dry and/or Near-dry Holes to End of 1936	Deepest Zone Tested to End of 1936	
	Sulphur, Per Cent	Base ^e	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Name	Age ^f	Character ^g	Porosity ^h	Net Thickness, Average in Feet	Structure ⁱ		Name	Depth of Hole, Ft.
126	2.8	A	<i>x</i>	<i>x</i>	Sundance	Jur	S	Por	35	A	5	Granite	4,119
127			<i>y</i>	<i>y</i>	Frontier	CreU	S	Por	35	A	10	Chugwater	3,460
128	0.2	M			Muddy-Dakota	CreU	S	Por	60	A	2	Sundance	4,207
129	0.37	M			Dakota	CreU	S	Por	50	A	1	Lakota	3,930
130													
131	0.26	M			Dakota	CreU	S	Por	110	A			
132	0.26	M			Sundance	CreU	S	Por	100	A			
133											11	Embar	5,627
134													
135	0.15	M	<i>y</i>	<i>y</i>	First Wall Creek	CreU	S	Por	110	Af			
136	0.16	M	<i>y</i>	<i>y</i>	Second Wall Creek	CreU	S	Por	65	Af			
137	0.4	M	<i>y</i>	<i>y</i>	Lakota	CreL	S	Por	20	Af			
138	1.3	M	<i>y</i>	<i>y</i>	Sundance	Jur	S	Por	70	Af			
139	2.3	A	<i>y</i>	<i>y</i>	Tensleep	Pen	S	Por	190	Af			
140										AF			
141	<i>y</i>	M			Shannon	CreU	S	Por	75	MuP	41	Granite	5,400
142	2.9	A			Embar	Per	L	Cav	75	A	2	Shannon	<i>y</i>
143	0.17	M			Quealy	CreU	S	Por	40	A	13	Tensleep	2,486
144	4.5	A			Tensleep	Pen	S	Por	150	A	5	Steele	6,931
145	<i>y</i>	A			Embar	Per	L	Cav	40	A	0	Tensleep	2,500
146	3.24	A			Sundance	Jur	S	Por	25	A	8	Embar	2,514
147	<i>y</i>	M			Tensleep	Pen	S	Por	150	A	2	Tensleep	2,705
148	<i>y</i>	A			Aspen	CreU	H	Fis	<i>x</i>	MC	65	Asmsden	4,255
149												Bear River	2,065
150	0.15	M			Wall Creek	CreU	S	Por	40	Af			
151	0.15	M			Steele	CreU	H	Fis	<i>x</i>	Af			
152										Af			
153	<i>y</i>	P			Mowry	CreU	S	Por	50	A	10	Frontier	3,140
154	<i>y</i>	A			Embar	Per	S	Cav	65	A	95	Madison	4,165
155	1.8	A			Embar	Per	L	Cav	35	A	18	Tensleep	1,590
156											5	Tensleep	4,246
157			1,060	0.25	Frontier	CreU	S	Por	50	A			
158			1,060	0.25	Dakota	CreU	S	Por	50	A			
159			1,060	0.25	Lakota	CreL	S	Por	40	A			
160			1,060	0.25	Sundance	Jur	S	Por	20	A			
161	1.4	A			Tensleep	Pen	S	Por	27	A			
162											2	Tensleep	5,886
163											1,721		

Late in 1936 the well cored the top of the Tensleep, found saturation, and the casing was cemented. When tested without deepening, the well showed for about 2000 bbl. of 35° gravity black oil per day.

Indications are that Wertz dome will become an important oil producer from the sand. Another effect of the test will be to speed up drilling of other untested structures in the vicinity to the same horizon.

The Muskrat structure consists of a number of small domes on a long anticline. One of these small domes yields gas from the Frontier sand, but several earlier tests and two subsequent ones were failures. In 1936 a test well capable of reaching all probable horizons was started on an untested local dome. The Cretaceous and Jurassic sands were found to be barren, but the Permian-Embar was found to be oil-bearing. Unfortunately, mechanical troubles developed, which prevented completely testing the well in 1936 and it was shut down for the winter. Indications are that the Permian and probably lower horizons will yield commercial oil.

A deep well drilled on the Gooseberry dome, Park County, developed mechanical troubles after coring good saturation in the Permian-Embar. Parting of the drill pipe prevented testing of this well, which is slated as an early discovery for 1937.

A most important discovery for Wyoming in 1936 was the completion of a commercial oil well in the Wasatch formation at Powder Wash, several miles south of the Wyoming line. The Wasatch is Eocene-Tertiary in age and the discovery at Powder Wash makes it obvious that the oil found there is indigenous to the formation. Gas in large volume was previously known from the Wasatch and is being produced at Hiawatha field in Colorado.

TABLE 2.—*Summary of Drilling Operations in Wyoming*

Important Wildcats Drilled in 1936							
	County	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested
		Sec.	Twsp.	Rge.			
		Survey	Lat.	Long.			
1	Park.....	16	57 N.	101 W.	8469	Fort Union	Frontier
2	Sweetwater.....	32	16 N.	104 W.	2754	Baxter shale	Frontier
3	Dutton Creek.....	1	18 N.	78 W.	5460	Steele shale	Sundance
4	Carbon.....	18	22 N.	78 W.	2088	Niobrara	Sundance
5	Washakie.....	14	48 N.	91 W.	2395	Cody shale	Frontier
6	Big Horn.....	Lot 53 I	56 N.	97 W.	4206	Cody shale	Madison
7	Park.....	33	47 N.	100 W.	5680	Cody shale	Embar
8	Washakie.....	25	48 N.	91 W.	1583	Cody shale	Frontier
9	Goshen.....	14	28 N.	63 W.	3062	White River Tertiary	Granite
10	Niobrara.....	32	36 N.	65 W.	4450	Pierre shale	Tensleep
11	Little Laramie.....	4	16 N.	75 W.	3886	Steele shale	Tensleep
12	Medicine Bow.....	35	21 N.	79 W.	5596	Mesaverde	Sundance
13	Musktrat.....	1	33 N.	92 W.	7293	Cody shale	Embar
14	Overland.....	5	19 N.	83 W.		North Park Tertiary	Sundance
15	Rock Creek.....	35	20 N.	78 W.	3210	Steele shale	Sundance
16	Wagh.....	7	44 N.	96 W.	4245	Cody shale	Tensleep
17	Wertz Dome.....	7	26 N.	89 W.	5883	Steele shale	Tensleep

The oil at Labarge is produced from sands in the basal Eocene, but was thought to have originated in underlying Cretaceous. It now seems obvious that the Labarge oil, being of the same character as the Powder Wash oil, is indigenous to the Tertiary. Other structures in both Wyoming and Colorado may be expected to yield Wasatch oil.

PRODUCTION PRACTICE

Oil-production practice has changed little in Wyoming in 1936. More attention is constantly being paid to gas drive or recirculations in connection with gas-lift, and it has been successfully used at Salt Creek, Lost Soldier, Grass Creek, Elk Basin, Rock Creek and Labarge. This practice will be much more extensively used in the future.

Much more attention is being paid constantly to the systematic spacing of wells. Most new fields are being drilled up on the basis of one well to 40 acres, with the wells located in the centers of the tracts. Wherever feasible the wells are being located not at the center, but at some specified corner of each forty, a system that later will allow doubling the number of wells, if necessary, without disturbing the regularity of spacing.

Much more care in coring producing horizons is being taken than formerly.

The use of Schlumberger apparatus was first applied in Wyoming during 1936. Geophysical methods of prospecting for structure are becoming prevailing practice and now are widely used in the state. More than a dozen seismograph crews were in operation in Wyoming during the field season of 1936. Several important geophysical highs will be tested in 1937.

TABLE 2.—(Continued)

Important Wildcats Drilled in 1936							
	Drilled by	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
		Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
1	Julius Peters et al.	200	1.5	Pump	200	50	Second well in field.
2	Mountain Fuel Supply		7.2		760		Extends gas area.
3	Union Oil Co.	None	None				Dry in Sundance.
4	Medicine Bow Oil Co.		25		1000		Discovery well.
5	Wyoming O. & R. Co.						Small dome; dry.
6	Stock Oil Co.	1600	0.2	1/4	1000	600	Extends field.
7	General Pet. Co.	Incomplete					Discovery well.
8	Yale Oil Corp.	135		Pump			New field.
9	Ohio Oil Co.	None	None				Test seismograph high.
10	Ohio Oil Co.	?	?	?	?	?	Mystery well.
11	California Co.	None	None				Small dome, dry.
12	Ohio-California Co.	2299	16	?	2000±	500±	New field.
13	Sinclair Wyo. Oil Co.	Incomplete					Oil discovery.
14	General Pet. Co.	None	None				Important failure.
15	Ohio Oil Co.	1000	Some			Flowing	Best well in new Sundance sand.
16	Honolulu Oil Co.	None	None				Second well and failure in new field.
17	Sinclair Wyo. Oil Co.	2000	2				Important oil discovery.

Developments in the Petroleum Industry in the Argentine

By GUILLERMO HILEMAN*

(New York Meeting, February, 1937)

PROBABLY the outstanding feature of the oil industry in the Argentine, during the past year, was the increase in production from the Comodoro Rivadavia field. This increase was accounted for by the discovery of a deeper producing horizon in the old coastal field (zone A). The oil, derived from the deeper sands, served not only to balance the natural decline of the upper sands and increase the yield from the area, but also provided a product of comparatively superior quality.

The finding of this new production in the old field had a special economic significance because of the pumps, tanks and pipe lines already installed to take care of it. The deep horizon is looked upon as a life

TABLE 1.—Oil and Gas Production in the Argentine

Line Number	Field, Province or Territory	Age, Years to End of 1936	Area Proved, Acres		Total Oil Production, Bbl.				Total Gas Production, Millions Cu. Ft.	
			Oil and Gas ^a	Total	To End of 1936	During 1935	During 1936	Daily Average during Nov. 1936	To End of 1936	During 1935
	Comodoro Rivadavia, Terr. Chubut									
1	Zone A.....	29	12,350	12,350	88,507,911	5,161,391	5,941,163	16,656	140,121	11,450
2	Zone B.....	12	14,820	14,820	27,423,488	5,038,025	5,527,325	16,486	19,419	4,833
3	Zone C.....	20	3,458	3,458	14,519,052	1,192,722	1,083,459	2,661	8,305	1,347
4	Zone D.....	3			24,362	14,286	610			
	Plaza Huincul, Terr. Neuquen									
5	Zone 1.....	18	267	267	1,467,984	72,045	80,474	208	1,255	128
6	Zone 2.....	10	1,082	1,082	2,302,183	292,837	342,641	1,000	4,858	835
7	Zone 3.....	12	494	494	8,288,427	554,400	599,645	1,635	7,564	818
8	Zone 4.....	2			25,396	2,163	23,235	75	777	
	Dept. Oran, Prov. Salta									
9	Zone Tartagal.....	10	494y	494y	3,077,760	265,029	315,972	1,025	4,560	639.6
10	Zone San Pedro.....	8	247y	247y	6,130,235	1,447,952	1,321,718	3,070	6,947	1,508.3
11	Zone Agua Blanca.....	10	62y	62y	671,131	197,745	127,316	277		
	Province of Mendoza									
12	Cachaeta.....	5	y	y	84,198	20,241	39,652	232		
13	Tupungato.....	2	y	y	37,797	16,209	19,700	107		
14	El Sosneado.....	11	y	y	210,998	17,253	20,776	88		
15	Total.....		33,274	33,274	152,770,722	14,292,298	15,445,680		193,806	21,558.9

* Footnotes to column heads and explanation of symbols are given on page 291.

Manuscript received at the office of the Institute Feb. 15, 1937.

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saver for the Yacimientos Petroliferos Fiscales (the Government oil company) and it is actively prosecuting the development of the new producing sands.

In zone D production was temporarily suspended.

The Plaza Huincul area showed an increase in production largely from the areas controlled by Y.P.F.

The Baguales area, lying to the northeast of the old fields at Plaza Huincul and controlled by the Government company, has excited considerable interest, though so far production cannot be classified as having attained commercial status.

Production during 1936 diminished in Salta. No new pools were found, though exploratory drilling was extremely active. This activity is being carried on into 1937.

Astra, a local private company, after drilling four wells in the Cerro Colorado area, in two of which small shows of gas were encountered, has given up its leases and retired from the province.

Production in the Province of Mendoza registered a small increase due largely to a number of shallow wells (of small production) drilled on the monocline off the granite of Cacheuta Mountain.

In the Territory of Santa Cruz, Y.P.F. drilled in a well, 8 km. north of the town of Las Heras, which, at a depth of 769 m. gave an initial

TABLE 1.—(Continued)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells							Depth, Average in Feet		Oil Production Methods at End of 1936					Pressure, Lb. per Sq. In. ^d			
	During 1936	Maximum Daily during 1936	Completed to End of 1936	During 1936		At End of 1936					Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells					Initial	Average at End of	
				Completed	Abandoned	Temporarily Shut Down	Producing Oil and Gas ^b	Producing Gas Only	Total Producing	Flowing			Pumping	Gas-lift	Miscellaneous	Injection into Reservoir ^c	1935		1936	
1	9,148	27	2,235	63	6	270	1,646	18	1,664	2,100	1,950	21	1,583	33	9	28	1,030	30.0	30.0	
2	4,450	14	379	83	1	60	231	10	241	3,600	2,950	16	206		9		730	35.0	35.0	
3	989	4	602	69	8	113	328	13	341	2,170	1,970		298		30		300	15.0	15.0	
4			5	1						2,650	2,300							55.0	55.0	
5	491	0.42	84	3	12	10	49		49	1,970	1,800		49			5	150.0	70.0	65.0	
6	597	2	126	21	10	18	93	4	97	2,400	2,170	9	84			1	210.0	118.0	105.0	
7	636	2	211	2	10	29	135	8	143	2,790	2,460		135			10	180.0	70.0	70.0	
8	777	1	3	1			2	1	3	3,300	3,280	1	1				40.0	0	0	
9	706	1.9	148	9	2	18	113		113	1,770	1,470	1	98	12	2		60.0	60.0	60.0	
10	1,342	1.7	37	2			19		19	2,800	1,790	11	6	1			600.0	580	500.0	
11			6				5		5	2,460	1,500	1		1						
12			30	8			15		15	2,000	1,996		13		2					
13			12	6		2	10		10	1,280	1,276	8	1		1					
14										552	547									
15	19,136		3,978	268	49	521	2,545	54	2,700			68	2,477	47	52	44				

production of 63 bbl. The commercial importance of this discovery is being corroborated by further drilling.

It is worthy of mention, in connection with the activities of the Government company, that Y.P.F.'s production during the year 1936 reached a new peak of 1,140,188 cu. m., which represents an increase over 1935 of 196,342 cu. m., or 20.8 per cent.

The net increase for the country at large was due to increases at Comodoro Rivadavia, Plaza Huincul and Mendoza, less a decrease in Salta.

At the close of the year a sales contract was signed between the Y.P.F. and the Standard Oil Company of the Argentine, whereby the latter agreed to sell out all its interests (producing, refining and marketing) to the Government company and retire from the Argentine for 15 years. The purchase price agreed on amounted to ₧140,500,000 (Argentine pesos), or approximately \$42,500,000 U. S. currency. The deal, however, is subject to Presidential and Congressional approval.

TABLE 1.—(Continued)

Line Number	Character of Oil, Approx. Average during 1936						Character of Gas, Approx. Average during 1936		Producing Rock						Number of Dry and/or Near-dry Holes to End of 1936	Deepest Zone Tested to End of 1936	
	Gravity A.P.I. at 60° F.					Base ⁶			B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Name	Age ⁷	Character ⁸	Porosity ⁴		Net Thickness, Average in Feet	Structure ⁵
	Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Bases ⁶												
1	24.0	20.6	22.0	0.18	M	854	0.51	Chubutiano and Glauconitico.	Cre	Ss	Por	29y	AF	119	Chubutiano	4,060	
2	34.6	20.5	28.0	0.18	M	854	0.45	Chubutiano and Glauconitico.	Cre	Ss	Por	33y	AF	88	Chubutiano	5,880	
3	21.3	19.0	20.0	0.18	M	850	0.12	Chubutiano and Glauconitico.	Cre	Ss	Por	13y	AF	90	Chubutiano	2,370	
4	23.2	23.2	23.2	0.18	M	850	0.20	Chubutiano and Glauconitico.	Cre	Ss	Por	26y	AF	3	Chubutiano	3,150	
5	34.4	33.4	34.0	0.20	M	905	1.54	Dogger	JuM	S	Por	39y	MU, AF	21	Dogger	2,500	
6	34.2	33.0	33.8	0.20	M	905	1.12	Dogger	JuM	S	Por	33y	MU, AF	7	Dogger	5,550	
7	34.2	33.0	33.8	0.20	M	905	1.11	Dogger	JuM	S	Por	33y	MU, AF	28	Triassic	2,900	
8	34.0	33.0	33.6	0.20	M	905	y	Dogger	JuM	S	Por	25y	MU, AF	2	Triassic	3,820	
9	45.0	43.9	44.0	0.10	P	917	0.84	Clay grit series	Per Carb	Ss	Por	33y	A	31	Gondwana	4,202	
10	46.0	44.7	45.0	0.10	P	917	0.84	Clay grit series	Per Carb	Ss	Por	29y	A	8	Gondwana	3,200	
11	23.2	22.8	23.0	0.10	P	917	0.30	Clay grit series	Per Carb	Ss	Por	20y	A	4	Gondwana	3,010	
12	31.2	27.0	28.0	0.14	P			Red beds	CreU	Ss	Por	13y	AF	4	Triassic U	3,550	
13	33.0	31.0	32.0	0.11	P			Calchaqueño	Ter	Ss	Por	16y	AF		Cretaceous	1,620	
14	13.0	11.0	13.0	1.20	A			Ranchhouse	Ter	Ss	Por	13y	MIF				
15								Conglomerate									

TABLE 2.—*Summary of Drilling Operations in the Argentine Republic*

Important Wildcats Drilled in 1936

	Province or Territory	Location	Well	Total Depth, Meters	Surface Formation	Deepest Horizon Tested	Drilled by	Initial Production per Day		Remarks
								Oil, U. S. Bbl.	Gas, Millions Cu. Ft.	
1	Chubut....	Comodoro Rivadavia	T4	1790	Miocene	Senonian	Y.P.F.			Structure well. Dry.
2	Chubut....	Comodoro Rivadavia	T34	1353	Miocene	Senonian	Y.P.F.	629		
3	Chubut....	Comodoro Rivadavia	S97	1279	Miocene	Senonian	Y.P.F.	629		
4	Santa Cruz	Las Heras	No. 4	769	Miocene	Senonian	Y.P.F.	63		
5	Plaza Huincul.....	Neuquen	N.E.4	1061	Senonian	Trias	Y.P.F.	150		
6	Salta.....	Campo Duran	C.D. 4	1402	Tertiary (Pli)	Terciari subandino (Pli)	Y.P.F.			Abandoned. Dry.
7	Salta.....	Campo Duran	C.D. 5	1947	Tertiary (Pli)	Terciari subandino (Pli)	Y.P.F.			Drilling.
8	Salta	Tranquitas	T. 64	1074	Tertiary (Pli)	Permo Carb	Y.P.F.	75		
9	Salta	Candelaria	C. 1	1525	Tertiary (Pli)	Trias	Standard Oil Co.			Abandoned. Dry.
10	Salta.....	Lomas del Inca	No. 1	915	Miocene	Oligocene	Standard Oil Co.			Abandoned. Dry.
11	Salta.....	Tomasito	No. 1	822	Tertiary (Pli)	Tertiary	Standard Oil Co.			Changing to rotary.
12	Salta.....	La Cruz	282-U-No. 1	697	Miocene	Trias	Ultramar			Suspended.
13	Salta.....	La Cruz	289-G-No. 1	1175	Miocene	Trias	Galena-Signal			Suspended.
14	Jujuy.....	Rio Dorado	294-G-No. 1	320	Tertiary (Pli)	Eocene	Galena-Signal			Suspended.
15	Jujuy.....	Cerro Colorado	No. 3	1089	Trias	Silurian	Astra		Show	Abandoned.
16	Jujuy.....	Cerro Colorado	No. 4	500	Trias	Trias	Astra			Abandoned.
17	Jujuy.....	Saladillo de la Brea	J.E. No. 1	1925	Tertiary (Pleis)	Trias	Y.P.F.			Dry in lower horizons. Shows in Cretaceous. Drilling.
18	Jujuy.....	Saladillo de la Brea	J.B. No. 1	1500	Tertiary (Pleis)	Cretaceous	Y.P.F.			
19	Jujuy.....	Saladillo de la Brea	J.B. No. 3	1582	Tertiary (Pleis)	Cretaceous	Y.P.F.	31		Noncommercial.
20	Jujuy.....	Saladillo de la Brea	J.B. No. 5	1065	Tertiary (Pleis)	Trias	Y.P.F.			Dry and abandoned.
21	Jujuy.....	Saladillo de la Brea	J.B. No. 7	930	Tertiary (Pleis)	Tertiary (Pli?)	Y.P.F.			Drilling.
22	Mendoza...	Pampa Amarilla	PA. No. 1	1200	Cretaceous	Oxfordian	Y.P.F.			Drilling.

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1936.....	53	32
Number of oil wells completed during 1936.....	268	5
Number of gas wells completed during 1936.....		
Number of dry holes completed during 1936.....	8	8

Petroleum Developments in Austria, Hungary and Czechoslovakia during 1936

BY BRANDON H. GROVE*

AUSTRIA

IN Austria's only producing field, at Zistersdorf, Erdoel Produktionsgesellschaft completed a single new producer, its well Gösting 6 coming in early in October for an average production of about 15 tons daily. For further testing within the proved part of the field this company's Gösting 7 was at the close of the year drilling in Pannonian strata at 760 m., and its Gösting 8 was rigging up.

Outside of the proved area of the Zistersdorf field two further tests located on the Steinberg dome failed to find production in the known oil-bearing strata of the Sarmatian, and were deepened as wildcats into the Cretaceous Flysch. The first of these, Neusiedel 1, about one kilometer north of the known producing area, found oil in the Flysch beds at a depth of 1290 m. for an initial production of about 10 tons per day. The second test, Windisch Baumgarten Ia, is an old well previously considered a failure, which when deepened achieved a production of about 5 tons per day in the Flysch *Inoceramus* beds at 985 m. Neither of the foregoing wells is producing from a stratigraphically definable horizon, oil accumulation in the Flysch of this area being apparently controlled by tectonic breccias or related crevices.

TABLE 1.—Oil and Gas Production in Czechoslovakia and Austria

Line Number	Country, Field	Age, Years to End of 1936	Area Proved, Acres				Total Oil Production, Barrels at 1 Metric Ton = 7 Bbl.			
			Oil	Oil and Gas ^a	Gas	Total	To End of 1936	During 1935	During 1936	Daily Average during Nov. 1936
1	Czechoslovakia, Gbely (Egball).....	23	350	y	y	350	1,927,520	68,978	79,191	y
2	Czechoslovakia, Hodonin (Göding).....	17	250	y	y	250	811,878	64,343	56,622	y
3	Austria, Zistersdorf.....	7	30	0	0	30	125,111	44,163	48,314	217

* Footnotes to table heads and explanation of symbols are given on page 291.

Manuscript received at the office of the Institute March 13, 1937.

* Socony-Vacuum Oil Co. Inc., Hamburg, Germany.

During the early part of the year well RAG 1, drilled by Rohöl Gewinnungs A.G. (Vacuum-Shell combination), adjacent to the southern margin of the proved area of the Steinberg dome, found shows amounting to nearly 20 tons in 48 hr., in the Sarmatian at 1021 m. The well was a technical failure, however, because with withdrawal of oil the thin shale bed above the producing sand progressively collapsed, permitting flooding from an overlying aquifer. Three successive high-pressure cementings were unable to correct this condition. The same company's RAG 2, begun in September, was at the end of the year engaged in fishing for a drill stem and bit which were frozen to a depth of 1389 m. This well, located lower on the structure than RAG 1, found the first seven Sarmatian sands water-bearing, but still has definite chances for production from underlying sands.

Elsewhere in the Vienna Basin (Fig. 1) the European Gas and Electric Co. (Standard Oil Co. New Jersey) drilled three unsuccessful wildcats: Podersdorf I, abandoned in basement granite at 376 m.; Enzersdorf II, abandoned at 1544 m. after testing the Sarmatian and finding all sands water-bearing; and Frauenkirchen I, abandoned in basement rock at 1625 m. in December.

During the year an effort was made to obtain further production from some of the European Gas and Electric Company's gas wells at Oberlaa, but the attempt was a failure and the field is now completely shut down.

The proved oil reserves of Austria, i.e., of the Zistersdorf field, have been estimated as of December, 1936, to amount to 192,000 tons (1,344,000 bbl.).

HUNGARY

There were no producing oil and gas wells in Hungary during 1936, and important drilling was confined to three wildcats undertaken by the European Gas and Electric Co. at Inke, Liske (Budafa-Puszt) and Görgeteg. At the close of the year the well at Inke was bottomed in marine Miocene at 2080 m. Its prospects for production are considered

TABLE 1.—(Continued)

Line Number	Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							Depth, Average in Feet		Oil Production Methods at End of 1936					Pressure, Lb. per Sq. In. ^a		
	To End of 1936	During 1935	During 1936	Maximum Daily during 1936	During 1936		At End of 1936					Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells					Average at End of		
					Completed to End of 1936	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Gas Only	Total Producing	Flowing			Pumping	Gas-lift	Air-lift	Bailing	Initial	1935	1936	
1 3	187y 0	11y 46y 0	7y 39y 0	y y 0	3y 12y 4	2y 1y 3	2y y 0	95y y	5y 2y 7	5 5 0	55y 2y 7	790 485 3,444	540 425 2,460	y y 0	5y y 7	y y 0	y y 0	y 2y 0	y y y	y y y	

essentially nil, but it is planned to deepen it for geologic information. The well at Lispe drilled in the Pannonian (Pliocene) throughout, and was terminated at 2200 m. still in this formation, after encountering oil traces in sandy strata at 1070 and 1440 m. The Görgeteg well was abandoned in June in the basal Pannonian at 2059 meters.

The only important new well known to be contemplated for 1937 is a Government test at Reesk.

CZECHOSLOVAKIA

The most important oil development in Czechoslovakia during 1936 was the success of the Apollo Company's test near Ratiskowice. Early in September this well came in with an initial daily production of 10 tons of light, paraffin-base oil under high pressure. The nature of the crude indicates that it is derived from the Paleogene Flysch, and emphasizes the importance of the oil-bearing possibilities of the Paleogene series in the Vienna Basin.

Other wildcats still drilling at the end of the year were those of the Bata shoe company, near Rohatec, and the Government test at Jasina (in extreme eastern Ruthenia). The former had reached a depth of 700 m. in the Sarmatian when last reported, while the Jasina well stood at 1100 m., with opinions differing as to whether the bottom formation was the Eocene or Cretaceous part of the Flysch. Production prospects for both wells are very small.

No unusual events occurred in the two producing oil fields, Gbely (Egbell) and Hodonin (Göding). In the Government-controlled enterprise at Gbely, production from the old field and the new (1934) extension together averaged about 40 tons per day. It is necessary to drill about two wells per month to maintain it at this level.

At Hodonin the Apollo Company's production for the year averaged a little over 20 tons daily.

At Mikova, in the Carpathians, about 20 tons of light, paraffin-base, Flysch oil was produced during 1936. This is very similar to the amounts

TABLE 1.—(Continued)

Line Number	Character of Oil, Approx. Average during 1936					Character of Gas, Approx. Average during 1936		Producing Rock						Deepest Zone Tested to End of 1936		
	Gravity A.P.I. at 60° F.			Sulphur, Per Cent	Base ^a			Name	Age ^f	Character ^g	Porosity ^h	Net Thick- ness, Average in Feet	Structure ⁱ			
	Maximum	Minimum	Weighted Average			B.t.u. per Cu. Ft.	Gal. Gas- line per M. Cu. Ft.									
														Number of Dry and/ or Near-dry Holes to End of 1936	Name	Depth of Hole, Feet
1	40.0	20	21	25	A, P	y	y	Sarmat	Mio	SH	y	1,066	AF	6y	Flysch (Eocene?)	5,122
2	40.0	18	19.0	y	A	y	y	Sarmat	Mio	SH	y	984	AF	2y	Mediterran (Mio)	2,411
3	32	19	22	y	A, P	y	y	Sarmat	Mio	SS	18	1,300	AF	5	Flysch (Cretaceous)	4,550



FIG. 1.—NORTHEASTERN PART OF THE VIENNA BASIN.

produced in the two past years, but it is reported that the Government contemplates a serious attempt at development here.

The proved oil reserves of Czechoslovakia have been roundly estimated at about $1\frac{1}{2}$ million barrels, divided nearly equally between the Gbely and Hodonin fields.

TABLE 2.—*Summary of Drilling Operations in Austria, Hungary and Czechoslovakia*

Important Wildcats Drilled in 1936						
	Country	Location			Total Depth, Meters	Surface Formation
		District	Lat.	Long.		
1	Austria	Lower Austria	48°34'	16°25'	1290	Pliocene
2	Austria	Lower Austria	48°32'	16°25'	990	Pliocene
3	Austria	Burgenland	47°48'	16°25'	167.5	Pliocene
4	Hungary	Transdanubia	46°05'	16°45'	2200	Pliocene
5	Hungary	Transdanubia	46°15'	16°30'	2059	Pliocene
6	Czechoslovakia	Moravia	48°55'	16°45'	470	Pliocene

Important Wildcats Drilled in 1936							
Deepest Horizon Tested	Drilled by	Initial Production per Day		Choke or Bean, In.	Pressure, Lb. per Sq. In.		Remarks
		Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
1 Senonian	Steinberg Nafta Ges.m.b.H.	70	4, 5	0.468	960	y	Dry in basement granite. Dry, gas shows. Dry.
2 Senonian	Raky-Danubia Co.	45	y	y	y	y	
3 Basement Granite	European Gas & Elec. Co.						
4 Pannonian	European Gas & Elec. Co.						
5 Lower Miocene	European Gas & Elec. Co.						
6 Sarmatian	Apollo Co.	70	y	y	y	y	

	Austria		Hungary		Czechoslovakia	
	In Proven Fields	Wildcats	In Proven Fields	Wildcats	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1936	1	1	0	1	y	3
Number of oil wells completed during 1936	1	2	0	0	± 40	1
Number of gas wells completed during 1936	0	0	0	0	y	0
Number of dry holes completed during 1936	0	4	0	3	y	0

Petroleum Development in Bahrein Island and Saudi Arabia during 1936

By J. O. NOMLAND*

(New York Meeting, February, 1937)

Bahrein Island.—In 1936 the Bahrein Petroleum Co. continued drilling additional wells to further increase production. In all, 39 flowing wells have now been finished and five others are drilling. A second well has been deepened for prospecting the deeper horizons but has not been successfully completed as a commercial producer. In addition, a well has recently been drilled near the eastern limit of the producing area for edge-water observation. The present system places wells 3000 ft. apart in a rhombic grid, or about one well to 179 acres. The total production for the year was 4,644,635 barrels.

It is expected that refinery capacity of 20,000 bbl. per day will have been completed by July, 1937.

A new permanent and enlarged camp with office buildings is being built. A new hospital has been constructed and two additional medical men have been added to the staff.

Saudi Arabia.—In eastern Saudi Arabia, the California Arabian Standard Oil Co. has continued with the program of prospect drilling started in 1935. After the gas encountered in Dammam well No. 1 had been successfully shut off, it was completed as a small flowing well of 51° gravity oil. Dammam No. 2, which had been started in 1935, tested 3840 bbl. of approximately 50° gravity oil from a depth of 2175 ft. Dammam No. 5, before being deepened for prospecting lower productive horizons, encountered a gas zone producing 30 million feet. Five other wells on the Dammam dome are in various stages of drilling or completion. Most of these have been located principally to outline the productive area and the various producing horizons of the structure. An extensive program of geological work is being continued.

In June, 1936, a well was started on the El 'Alat structure about 25 miles northwest of the Dammam development. Although various tar showings have been reported, the well has not yet, at 2518 ft., reached the depth at which it has been thought that productive horizons might be encountered.

A prospect well is being drilled by the Kuwait Oil Co. (jointly owned by Gulf and Anglo-Iranian Oil Companies) in the Sheikdom of Kuwait. The well is near Bahra, a few miles north of Kuwait Bay and about 240 miles northwest of El 'Alat. To date no favorable results at depth of about 6000 ft. have been reported.

Manuscript received at the office of the Institute Feb. 5, 1937.

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Petroleum Development in Bolivia during 1936

BY JORGE MUÑOZ REYES* AND GUILLERMO MARIACA*

(New York Meeting, February, 1937)

As far as technology is concerned there has been no development in Bolivia during the year 1936, because the country, just emerging from the war with Paraguay, is only beginning to rebuild its economic foundations. Great steps, however, are being taken in order to secure a rapid and sound development of its oil resources, as follows:

1. The new Petroleum Law, which contemplates the problem of proration and conservation of natural resources, prohibiting the wasteful use of gas, and regulating the number of wells, their spacing and the permissible output per well, for each particular pool according to the conditions prevailing therein.

2. The creation of an official entity with the object of developing and exploiting a large petroliferous area. This entity has been called Yacimientos Petroliferos Fiscales Bolivianos (Y.P.F.B.), and the region assigned to it is all the sub-andean zone, which is approximately one hundred miles wide and borders the eastern part of the Oriental Andean range, from Argentine to Peru. It is said that drilling will be started immediately in various localities.

At the present time a wide geological survey of part of the area is being made in order to find out which regions offer the best possibilities of commercial development. Y.P.F.B. has been authorized by the Government to draw up contracts with private companies for the exploitation of limited zones.

PRODUCTION

The only company that has been producing in the country in 1936 is the Standard Oil Company of Bolivia, and only from two of its fields: Camiri and Sanandita. New wells were not drilled.

During the first nine months of the year 12,762,958 liters (80,275 bbl.) was produced, 34,985 bbl. from the Camiri field and 45,290 bbl. from the Sanandita field. Reports for October, November and December are not yet available. The total for the year 1935 was 25,978,737 liters (163,388 bbl.).

Manuscript received at the office of the Institute Feb. 8, 1937.

* Direccion General de Minas y Petroleo, La Paz, Bolivia.

From January through September the following petroleum products were produced: gasoline, Camiri field, 3,233,849 liters and Sanandita field, 2,343,161 liters—a total of 5,577,010 liters (3507+ bbl.); aviation gasoline, Camiri field, 174,384 liters (1096+ bbl.); kerosene, Camiri field, 99,540 liters (626+ bbl.); and fuel oil, Camiri field, 1,634,205 liters and Sanandita field, 4,029,557 liters—a total of 5,663,762 liters (35,622+ bbl.).

Petroleum Industry in Burma, 1935-1936

BY L. DUDLEY STAMP*

(New York Meeting, February, 1937)

THE years 1935 and 1936 have been momentous ones in the history of oil exploitation in Burma. While the possibilities of the discovery of an important new field in the country have become increasingly remote, there have been surprising and to some extent unexpected developments in and near the old established fields. Further, these developments have not only an important bearing on the future of the industry in Burma, but they point to conclusions of world-wide significance in connection with the disposition of oil pools.

BURMA INDEPENDENT OF INDIA

According to the Government of India Act, passed by the British Parliament in 1935, Burma becomes independent of India, of which it was formerly a province. In future, therefore, statistics for Burma will be quoted separately from those of India. In 1934, 1935 and 1936 the oil production in India (including Burma) reached new high levels—though only a few per cent above the totals for 1919, 1920 or 1930. Part of the increase came from Assam, so that Burma's total is apparently below that of 1921. It must always be remembered, however, that Burma's largest potential producer—Singu—is used essentially by the Burmah Oil Co. as a reserve and its production is varied from year to year, and indeed from week to week, according to local market demand or the requirements of the Rangoon refinery. The figures of Table 1 must therefore be viewed in the light of these remarks.

TABLE 1.—*Production in India and Burma*
IMPERIAL GALLONS^a

Year	India (Including Burma)	Burma
1931.....	305,018,751	243,914,568
1932.....	308,606,031	247,570,295
1933.....	306,009,022	249,000,899
1934.....	322,025,280	254,760,070
1935.....	322,662,336	251,338,974
1936 (estimated).....	335,000,000	268,000,000

^a 249 Imperial gallons = 1 metric ton of 7 bbl. (approx.).

Manuscript received at the office of the Institute Feb. 12, 1937.

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YENANGYAUNG

This field has been known and worked for over a hundred years, by machine wells since 1888. From the original area of about 1000 acres, 4,000,000,000 gal. of oil have been obtained and there are over 3000 producing wells. The whole field is electrically operated, the utmost care is taken to protect the oil sands from flooding by water, and the conservation of the gas pressures is a matter of first consideration. In the "native reserves," with their closely spaced competitive wells, vacuum (to a degree agreed upon between the operating companies) is applied, while back pressures are applied to youthful wells. On the larger blocks leased by the Burmah Oil Co., gas drives are used and gas is also injected, both for storage and repressuring.

In 1926 the geological staff of the B.O.C. made the important discovery that the fold is slightly asymmetrical, with gentler dips to the east. Gradually the deeper sands, which are gas or water sands along the superficial crest, have been found to be oil-bearing up to 5000 ft. on the eastern flanks. As a result the proved extent of the field has been doubled since 1926.

It has long been known that the field was crossed by many transverse or dip faults. The fault planes are often filled by mud (mud veins) and many of the oil sands have thus been effectively sealed. This accounts for the varying yield of wells often only a few yards apart but it has only recently been recognized that considerable oil pools have been sealed off far down the southern pitch. Thus separate oil pools beyond the old southern limits of the field are now being located and explored. The first was detected in 1930, when oil was struck at 4100 ft. south of the Minlindaung fault, $1\frac{1}{2}$ miles south of the old limit. In 1931 a small production was obtained from 5000 ft. a mile still further south. The square-mile block (4S) between these two strikes has become, in 1935 and 1936, the chief reserves of the important British Burmah Petroleum Co., Ltd., and the Burmah Oil Co. has practiced offsetting on the margins of the block.

SINGU

This field is probably the richest in Burma. The main part is held by the Burmah Oil Co. and the production is varied by it at will. Many years ago, the Rangoon Oil Co. took up blocks in the south despised by the Burmah Oil Co. because they were some distance away down the somewhat steep (8° to 20°) southerly pitch. This area proved a valuable reserve of the British Burmah Petroleum Co.—the oil sands occurring at depths of over 3000 ft. *below* an extensive series of water sands. Hence this southern extension of the field was located only by deep tests after passing through unpromising water sands.

It was not, however, realized until recently that this southern pool was held up in the same way as the southern pools at Yenangyaung—by cross faults sealed by mud. Nearly two miles farther south, an extensive pool has been located and is now being actively developed by the Indo-Burma Petroleum Co. (I.B.P.) and British Burmah Petroleum Co. (B.B.P.), operating jointly as the Pyinma Development Company, Ltd. (P.D.C.), and in competition with the Moolla Oil Co. and Burmah Oil Co., whose concession is to the east. The width of the new pool is still unproved.

At the northern end the Singu field is truncated abruptly by the River Irrawaddy and the Burmah Oil Co. is now embanking a part of the river bed, which is exposed in the low-water season, so as to increase its area.

LANYWA

The Singu field must obviously continue under the Irrawaddy River and the Indo-Burma Petroleum Co. carried on the bold policy of enclosing a sand bank, 2 miles long, on the opposite shore by a wall costing a million dollars. The work was carried out in three low-water seasons (1925-26, 1926-27, 1927-28) and the first well was commenced in 1927. By the end of 1933, there were 50 productive wells, and the production neared 30,000,000 gal. a year. The wall was extended later to over 2 miles and is now (low-water season of 1936-37) being extended still farther. The problem of recovering the oil under the actual bed of the great Irrawaddy is now being seriously discussed—oblique drilling and wells with derricks in tunnels under the river have both been suggested.

Lanywa is Burma's model field. Gas from the oil sands and separate gas sands is sent first for gasoline extraction at the company's plant, which recovers approximately one gallon of gasoline per 1000 cu. ft. of gas. The residual dry gas is used to generate power at a central station, from which the wells are electrically pumped and the machine shops operated. Back pressures are applied at most wells.

YENANGYAT AND SABÈ

The very old, small and apparently exhausted fields of Yenangyat and Sabè have taken on a new lease of life as a result of much drilling activity in 1934, 1935 and 1936. At Yenangyat a 3500-ft. sand was discovered below 2000 ft. of barren rocks. The field has large gas resources not yet used.

OTHER FIELDS

The other fields of Burma are all small but their limited production has been maintained except in those along the Indian Ocean, where production is now negligible. The northernmost field of central Burma, Indaw, has been steadily developed and the majority of the wells are now

operated by an automatic gas-lift. Attention has recently been paid to the extensive gas resources of Burma. The Pyayè gas field, located and investigated by the writer in 1923, gave a gas well that yielded 30,000,000 to 40,000,000 cu. ft. of gas daily for many months before being successfully closed in. The gas is now used as fuel in a cement factory—the first direct use of natural gas in Burma.

Petroleum and Natural Gas Developments in Canada during 1936

By G. S. HUME*

(New York Meeting, February, 1937)

THE total production of crude oil in Canada showed only a small improvement in 1936 over 1935, but developments of great importance took place in Alberta on the west flank of the Turner Valley field in the foothills southwest of Calgary. These have led to renewed activity in drilling such as has not been experienced for many years, and undoubtedly this will result in a very considerable increase in the oil production during 1937.

TABLE 1.—*Production of Petroleum in Canada*
Barrels of 35 Imperial Gas = 42 U. S. Gallons

	1935	1936 ^a
Alberta.....	1,245,871	1,307,460
Ontario.....	165,041	165,468
New Brunswick.....	13,359	18,377
Northwest Territories.....	5,115	5,400
Total.....	1,429,386	1,496,705

^a Production estimated by the Mining, Metallurgical and Chemical Branch, Dominion Bureau of Statistics, Ottawa.

TABLE 2.—*Production of Petroleum in Alberta*

	1935	1936
Turner Valley.....	1,215,599	1,274,650
Red Coulee border.....	14,772	17,790
Wainwright.....	15,500	14,713
Skiff.....		310
Total.....	1,245,871	1,307,463

The production of petroleum in Canada for the last two years is given in the accompanying tables. Production in Alberta is shown in Table 2.

Manuscript received at the office of the Institute Feb. 4, 1937.

* Geological Survey of Canada.

TABLE 3.—*Production of Natural Gas in Canada*
Thousands of Cubic Feet

	1935	1936
Alberta.....	15,700,000	16,843,957
Saskatchewan.....	75,558	90,739
Manitoba.....	600	600
Ontario.....	7,800,000	9,410,730
New Brunswick.....	615,454	601,850
Total.....	24,191,612	26,947,876

The outstanding petroleum development in Canada during the year was the completion of the Turner Valley Royalties well on the west flank of the southern end of the Turner Valley field, Alberta, southwest of Calgary. This well reached the top of the producing Paleozoic limestone at a depth of 6396 ft. and was completed in June at a total depth of 6828 ft. The well initially flowed 850 to 875 bbl. of 44° A.P.I. gravity oil and 2000 M. cu. ft. of gas per day. Since that time it has been cut down to about 750 bbl. a day, and this flow has been steadily maintained. As is known, the wells on the higher structural parts of the Turner Valley field mainly produce natural gas with a variable amount of high-grade naphtha. For the past six years, however, model No. 1 well¹ on the west flank of the north end of Turner Valley and 12 miles distant from the new Turner Valley Royalties well has produced crude oil. The oil from this well originally was 68° A.P.I. gravity as compared with 46° A.P.I. gravity at present. This well over a period of 6¼ years to July 1936 has yielded 322,909 bbl. of oil. The finding of crude oil on the west flank of Turner Valley in the south end of the field, therefore, was not surprising, but the size of the well has attracted wide attention and has led to much drilling activity. One of the remarkable features of Turner Valley is the relief of the producing zone of the Paleozoic limestone within the field. The highest structurally located well in Turner Valley, namely Royallite No. 14 well, reached the top of the Paleozoic at a depth of 3220 ft. or 786 ft. above sea level, whereas Turner Valley Royalties well reached the same horizon at a depth of 6396 ft., or 2155 ft. below sea level. Thus the relief of the Paleozoic limestone within the producing area has now been proved to be 2941 ft. with the lower limit of the oil zone not yet reached on the west flank.

Since the completion of Turner Valley Royalties well in June, two other crude-oil wells, Foundation Royalties No. 1 and Sterling Pacific No. 3, were completed in 1936. Neither of these wells is quite as low structurally as Turner Valley Royalties well and neither has so far given

¹ See J. S. Spratt and V. Taylor: *Bull. Can. Inst. Min. and Met.* (Nov. 1936) 715.

as large a daily yield. Experiments have been tried with various sizes of tubing to increase the flow but as yet no official production figures have been published. During 1936 there were 9 wells completed in Turner Valley and at the end of the year there were 10 drilling, with permits having been issued for several more to begin immediately.

Outside of Turner Valley there were several areas in the foothills where drilling was done. On the Jumpingpound structure west of Calgary, the Northwest Company Limited drilled two wells in an attempt to find crude oil in the upper Lower Cretaceous strata. Both attempts were unsuccessful. In the Red Deer foothills area, 60 miles north and 60 miles west of Calgary, close to the mountain front, Hunter Valley well continued drilling throughout the year. A depth of 6965 ft. was reached and the well is now reported to be close to the top of the Paleozoic limestone. A much greater thickness than expected of Lower Cretaceous strata was present in this well, but as far as known no faults of any magnitude have been encountered. Shows of oil and gas have been reported but none of these has been tested.

In the Plains area a well began in the Alberta syncline east of the foothills. It reached the top of the Paleozoic at 8750 ft., but has not yet been completed. This is the deepest well to date drilled in Canada. Drilling has been continued in a number of other areas on the Plains but no new fields were discovered nor were there any completions in the older producing fields.

There was no drilling for oil in the Northwest Territories during 1936. Two wells on the banks of Mackenzie River, 50 miles north of Fort Norman and about 100 miles south of the Arctic Circle, are producing sufficient oil to supply the demands for local use and for the mineral developments now taking place on Great Bear Lake. A small refinery is operated at the wells during the summer months.

In the southwestern peninsula of Ontario between lakes Huron, Erie and Ontario, the search has been for natural gas rather than for oil. The Brownsville field, in Oxford County near Tillsonburg, was discovered late in 1935. The most outstanding development in Ontario in 1936 has been in this field; 14 wells have been completed, of which 11 produced gas. The daily open flow of the field amounted to 15,604 M. cu. ft. per day of which the largest well was 4300 M. cu. ft. The producing horizon is the top of the Guelph (Silurian) formation at a depth of 895 to 915 ft. In Dawn Township, Lambton County, a gas well with a capacity of more than 20,000 M. cu. ft. was completed. During the year the city of London was supplied with gas from the Dawn field.

Petroleum Development in Colombia during 1936

By O. C. WHEELER,* MEMBER A.I.M.E.

(New York Meeting, February, 1937)

THERE was a marked increase in the investigation of undeveloped areas in Colombia during 1936. The Shell company commenced geological and geophysical investigations on an intensive scale in the Upper Magdalena Valley and at the end of the year had several geological and geophysical parties working in that area. These investigations were supplemented by aerial photography and it is understood that negotiations are under way for having this work continued. The Shell is reported to have acquired some options and leases on private properties in the Upper Valley region and in the western part of Cundinamarca. The Socony Vacuum was making preparations to begin seismograph work on its property north of the Sogamoso River, acquired in 1934 from Señor Luciano Restrepo. This company will probably start drilling on the property during 1937. The Richmond Petroleum Co. (Standard of California) is said to have renewed geological investigations in the Upper Magdalena Valley above Honda. Local Colombian interests took an active part in applying for concessions on nationally owned lands in the area between the Carare and Magdalena Rivers. The application of the Sociedad Nacional del Carare for a concession in this area was granted during the year. Subsequently an agreement was reached between this

TABLE 1.—Oil and Gas Production in Colombia

Line Number	Field, County	Age, Years to End of 1936	Area Proved, Acres		Total Oil Production, Bbl.				Total Gas Production, Millions Cu. Ft.		
			Oil	Total	To End of 1936	During 1935	During 1936	Daily Average during Nov. 1936	To End of 1935	During 1935	During 1936
1	Infantas, Santander.....	18	x	z	106,254,575	6,937,962	6,364,429	16,703	127,124	12,335	12,041
2	La Cira, Santander.....	10	z	z	79,569,072	10,659,692	12,391,680	34,257	88,905	11,494	16,416
3	Petrolea, Santander del Norte.....	4									
4	Rio de Oro, Santander del Norte.....	16									
5	Las Monas, Santander.....	9	x	z	y	y	y	y	x	x	x

¹ Explanation of symbols is given on page 241.

Manuscript received at the office of the Institute Feb. 17, 1937.

* Chief Geologist, International Petroleum Co. Ltd., Toronto, Canada.

company and the Tropical Oil Co. whereby the two would jointly test the property.

Colombian Petroleum Company.—Holdings of this company (Gulf interests) were acquired during the year by the joint interests of the Texas Company and the Socony Vacuum. Most important of the properties that went with this transaction was the Barco Concession. An interesting account of the history and development of this concession appeared in *Oil Weekly*, (Dec. 21, 1936).

The summary of developments on this property during 1936 was not received in time to be included in this paper. Drilling was continued, however, both on the Petrolea and on the Rio de Oro structures. The most important development was perhaps on the latter, where Oro No. 2 was abandoned at a depth of 6717 ft. Oro No. 3 was reported to be drilling below 5000 ft. It is understood that 13 wells have been drilled to the end of 1936 on the Petrolea structure, most of which were productive.

Tropical Oil Company.—Completions by the Tropical Oil Co. consisted of 45 wells, of which 44 were productive and one a failure. In addition, one of the wells in the La Cira field that previously produced from a shallow horizon was deepened to the C-zone. The abandoned well was drilled in the Infantas field as a test of the Cretaceous series. Drilling operations were suspended at a depth of 4048 ft., owing to the presence of salt water. Another location has been made to test the Cretaceous on the Infantas structure.

Operations were continued on the Tropical's Putana concession. Well No. 1 Lisama had reached a depth of 4729 ft. at the end of the year. The second well, No. 2, was drilled for a source of fuel oil and was completed as a small producer at a depth of 2793 feet.

Production from the Infantas and La Cira fields amounted to 18,756,-109 bbl., of which 272,385 bbl. was petroleum condensate added to crude. Production was at the highest level since 1930. A substantial part of

TABLE 1.—(Continued)

Line Number	Number of Oil and/or Gas Wells						Depth, Average in Feet		Oil Production Methods at End of 1936					Pressure, Lb. per Sq. In. ^d		
	Completed to End of 1936	During 1936		At End of 1936			Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells				Injection into Reservoir ^e	Initial	Average at End of	
		Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Total Producing			Flowing	Pumping	Gas-lift	Air-lift			1935	1936
1	452	0	1	112	533	533	1,000-2,600	400-2,200	32	501	0	0	30	x	x	x
2	326	43	0	65			600-4,180	400-3,980					16			
3																
4																
5	9	0	0							Shut in				x	x	x

the year's production was obtained from upper sands that formerly had been cased off in the C-zone wells. These upper sands, known as the B-zone, were opened by gun perforating. In addition to adding to the production of the field, the oil from these upper sands was effective in reducing the gas-oil ratio of production from deeper sands, so that a number of the wells that formerly had been closed in to prevent gas wastage were opened up.

TABLE 1.—(Continued)

Line Number	Character of Oil, Approx. Average during 1936					Character of Gas, Approx. Average during 1936		Producing Rock					Number of Dry and/or Near-dry Holes to End of 1936	Deepest Zone Tested to End of 1936	
	Gravity A.P.I. at 60° F.			Base ^e	Name			Age ^f	Character ^g	Porosity ^h	Net Thickness, Average in Feet	Structure ⁱ		Name	Depth of Hole, Ft.
	Maximum	Minimum	Weighted Average			Sulphur, Per Cent									
							B.t.u. per Cu. Ft.								
1	36	23	26.3	0.90	A	1,050	A, B and C zones	Oli, Eoc	S	15-22	50-200	AF	13	Cre	4,048
2	27	20	24.0	0.90	A	1,050	A, B and C zones	Oli, Eoc	S	15-25	50-175	AF	1	Cre	3,536
3	y	y	y	y	A	x	y	Eoc, Cre	S	y	y	A	4	CreU	5,434

Production of Oil in Egypt in 1936*

(New York Meeting, February, 1937)

THE Hurghada field is still the major producing field in Egypt. There was almost no activity in the Abu Durba field during 1936 and no new evidence is available. The following table summarizes the information on the Hurghada field for the year 1936.

HURGHADA FIELD	
Age of field to end of 1936, years.....	23
Producing area for gas and oil, acres.....	1,050
	BARRELS ¹
Total oil production to end of 1936.....	29,046,572
Total oil production during 1935.....	1,212,182
Total oil production during 1936.....	1,218,708
Daily average during November, 1936.....	3,249
	MILLIONS CU. FT.
Total gas production (Aug. 1925 to end of 1936).....	3,966
Total gas production during 1935.....	278
Total gas production during 1936.....	280
Maximum daily in 1936.....	0.9
Number of producing wells completed to end of 1936...	94
Number of producing wells completed during 1936....	3
Number of wells abandoned during 1936.....	3
Producing wells at end of 1936.....	76 ²
Average depth of bottom of producing wells, ft.....	1,720
Average depth of top of producing horizon, ft.....	1,598
Character of oil, approx. average during 1936:	
Gravity at 60° F., 0.900; base mixed.	
Character of gas, approx. average during 1936: gallons gasoline per 1,000 cu. ft., 6.2.	
Producing rock (main): Nubian sands, Cretaceous; character, sand rock and sandy shales.	

¹ The figures given by the author were in tons. A conversion factor of 6.98, based on 0.900 sp. gr., was used to obtain the number of barrels.—Ed.

² All pumping.

* Information received through the courtesy of the Controller of the Egyptian Department of Mines and Quarries, Dawawin P. O., Egypt. Figures received Feb. 2, 1937.

Oil and Gas in France and French Colonies in 1936

BY H. DE CIZANCOURT*

As in former years, Pechelbronn, in Alsace, was the most important producer in 1936, with 484,453 bbl., of which 283,151 from drilling and 201,302 from mining showed a slight increase in comparison with the preceding year.

Gabian, in France and Tliouanet, in Algeria, are nearly exhausted. At Gabian, four wells drilled in intermittent exploitation produced during the year 2893 bbl. Four wildcats, one of which is producing, constituted all the activity in research on French territory.

In Morocco, some wildcats have been drilled in search for new fields and exploratory drilling has been done in Tselfat and in Djebel Bou Draa in known fields, but the results have been inconsiderable.

In Tunisia there was a gas outburst in Kebir 1, which is the first practical result obtained.

In Madagascar, the Andrafiavelo region has been left and a new region has been tried in Folakara with the Tsimororo.

In French Equatorial Africa, one drilling is in progress.

TABLE 1.—*Oil and Gas Production in France and French Colonies*

Line Number	Field	Age, Years to End of 1936	Area Proved, Acres		Total Oil Production, Bbl.				Number of Oil and/or Gas Wells		
			Oil	Total	To End of 1936	During 1935	During 1936	Daily Average during Nov. 1936	Completed to End of 1936	During 1936	
										Completed	Abandoned
1	France Pechelbronn, <i>Bas-Rhin</i>	201	75,350	75,350	14,947,912	538,931	484,453	1,277	3,856	57	33
2	Gabian, <i>Herault</i>	12	14		158,014	3,233	2,893				
3	Algeria Tliouanet.....	25	30		196,077	2,663	2,297				

Manuscript received at the office of the Institute March 3, 1937.

* Compagnie Française des Petroles, Paris, France.

TABLE 1.—(Continued)

Line Number	Number of Oil and/or Gas Wells		Depth, Average in Feet		Oil Production Methods at End of 1936		Character of Oil, Approx. Average during 1936					Producing Rock	Deepest Zone Tested to End of 1936		
	At End of 1936		Bottoms of Pro-ductive Wells	To Top of Pro-ductive Zone	Number of Wells		Gravity A.P.I. at 60° F.			Sulphur Per Cent	Base*	Age†	Character‡	Name	Depth of Hole, Ft.
	Producing Oil Only	Total Producing			Pumping	Mining	Maximum	Minimum	Weighted Average						
1	617	617	1,350	1,000	617	3 shafts	17.4	35.	25.	0.03	M	{ Oligocene Jurassic Triassic Triassic Miocene	S O D D S	Middle Triassic	3,135
2															
3															

*Footnotes to column heads and explanation of symbols are given on page 291.

TABLE 2.—Drilling Operations in France and French Colonies

Important Wildcats Drilled in 1936

Country	Location	Total Depth, Ft.	Deepest Horizon Drilled	Drilled by	Remarks
France.....	Chilly, Hte. Savoie	600	Lower Cretaceous (Urgonian)	Government	Drilling at end of year.
	Pezenas (Herauld)	2400 1800		Government Government	Drilling at end of year. To be completed at 3600 ft.
	Sainte Colombe	3327		Private company	Completed in 1936.
Morocco	Djebel Tselfat	5980	Liassic (Jurassic)	Société Cherifienne des Petroles	Completed in 1936: eight wildcats, dry; seven in producing fields. Drilling at end of year: six wildcats and two in producing fields. Total feet drilled in 1936 in Morocco: 29,200.
Beker 2.....	20 km. WSW. Ouezzan	6673	Eocene	Société Cherifienne des Petroles	
Tratt 1.....	6 km. WNW. Fez	2178	Liassic	Société Cherifienne des Petroles	
Bou Draa 3....	1 km. E. Petitjean	3904	Liassic	Société Cherifienne des Petroles	
Tunisia	Amar 1.....	3016	Lower Cretaceous	Syndicat d'Etudes et Recherches Petrolieres	Completed.
	Debbous 1.....	3828	Lower Cretaceous	Syndicat d'Etudes et Recherches Petrolieres	Drilling at end of year.
	Kebir 1.....	2825	Upper Cretaceous	Syndicat d'Etudes et Recherches Petrolieres	Drilling at end of year.
Madagascar	Tsimororo 1...	2640		Syndicat d'Etudes et Recherches Petrolieres	Drilling at end of year.
French Equatorial Africa	Madiela 2.....	2435	Lower Cretaceous	Syndicat d'Etudes et Recherches Petrolieres	Completed.
	Kongo 1.....	1168	Upper Cretaceous	Syndicat d'Etudes et Recherches Petrolieres	Drilling at end of year.

Petroleum Development in Germany during 1936

BY WALTER KAUNHOWEN*

(New York Meeting, February, 1937)

GERMANY's crude-oil production during 1936 totaled 3,112,494 bbl., an increase of 5.2 per cent over the 3,007,711 bbl. produced in 1935.

The official monthly production figures published in 1936 report only the individual production figures of the three old established fields, whereas since 1936 official reports combine the production of all other fields into one figure. According to these published data, and using a conversion factor of 1 metric ton equaling 7 bbl., the oil production of Germany in 1936 was as follows:

Field	Production in 1936, Bbl.	Percentage of Total Production, 1936
Nienhagen.....	2,332,862	74.9
Wietze.....	327,845	10.6
Oberg.....	161,875	5.2
All other fields.....	289,912	9.3
	3,112,494	100.0

Manuscript received at the office of the Institute Feb. 17, 1937.

* Deutsche Vacuum Oel A. G., Hamburg, Germany.

Search for Oil in Great Britain by D'Arcy Exploration Company Limited*

(New York Meeting, February, 1937)

THE D'Arcy Exploration Company Ltd. has been granted prospecting licenses in Great Britain to explore four different types of prospect. In the south of England (Dorset, Hampshire and Sussex) the objective lies in Jurassic and Lower Cretaceous beds. In an area of approximately 4470 sq. miles, covering parts of Nottinghamshire, Lincolnshire and Yorkshire, the search is directed to testing Carboniferous rocks. In northeastern Yorkshire a single license covers structures in which the Permian limestone will be explored. In Scotland, southeast of Edinburgh, the company holds another single license where Lower Carboniferous horizons are the objective.

SOUTHERN ENGLAND

Among the more important "indications" that led D'Arcy Exploration Company Ltd. to undertake a testing program in southern England was the discovery of sands in the Wealden (Lower Cretaceous) series of Dorset, impregnated with oil residues. Traces of oil and bitumen were also found in limestones of the Portland and Purbeck beds of the same area. In addition, traces of petroleum had been recorded from Upper and Lower Jurassic beds in borings, more especially those drilled in the course of coal exploration in Kent and Sussex, and an outcropping oil sand was known to occur in Wealden beds near Pevensy in Sussex.

Besides these tangible proofs that at least some oil has been generated in this area, the Jurassic beds, as developed at outcrop in Dorset and elsewhere, include considerable thicknesses of strata that may well be considered as possible source rocks of petroleum. A regional view suggested that these possible source rocks extended, without great thinning, beneath at least the southerly parts of the Weald of Sussex, the South Downs and still farther south beneath the English Channel. It appeared, and still appears, a reasonable conclusion that, where suitable structural conditions occur in this tract of country, an oil accumulation of commercial value may be found.

Of the several possible anticlinal structures, those at Portsdown (Hampshire) and between Henfield and Steyning (Sussex) were selected as sites for the first test wells. The groups of strata which at outcrop sug-

* Received through the courtesy of the Anglo-Iranian Oil Co., Ltd., London, England. Manuscript received at the office of the Institute Feb. 10, 1937.

gest source conditions are the Kimeridge and Oxford clays of Upper Jurassic age, and the Lower Jurassic (Lias) shales. When drilling began, the chief outcropping oil residues known were those of the Portland, Purbeck and Wealden beds. In these stratigraphic groups it was hoped that suitably porous reservoir horizons would be found into which oil had migrated from the Kimeridge or even deeper rocks below. The Portland, Purbeck and Wealden were thus the first objective, though it was decided also to test deeper Jurassic horizons down to the base of the Lias.

During the early stages of the drilling, an outcropping sand in Corallian beds, exposed near Osmington mills in Dorset, was found to be heavily impregnated with oil; the sand, where it passes below high-tide level, was found to seep oil of good quality. This discovery further raised the prospects of finding an oil accumulation in Corallian beds of Portsdown, Henfield and elsewhere in southeastern England.

The Portsdown test well has now reached the Lias, and the Henfield well is in Inferior Oolite limestones. The tests, so far, have not realized the best that was hoped for from them: they have not found oil in commercial quantity in Middle or Upper Jurassic or in Lower Cretaceous beds. The deepest horizons of the Lias are still untested.

The suggestion has frequently been made that the Paleozoic floor, which beneath London lies within 1000 ft. of surface, again rises to comparatively shallow depths under the southern flank of the Weald anticlinorium. Had this been true a great thinning or even complete absence of Jurassic beds might have been found in Portsdown and the prospects of finding oil in either that structure or in Henfield would have been materially reduced. It was the view of D'Arcy Exploration Co. that the evidence for such a Paleozoic ridge or platform beneath the south coast of Sussex was insufficient, and the boreholes have amply justified that view.

In Portsdown, beneath a normal thickness of Chalk and Gault-Upper Greensand, there is only 92 ft. of Lower Greensand, 785 ft. of Wealden beds developed in a silt and clay facies with few sands, 251 ft. of Purbeck beds similar to those of the Isle of Purbeck, and 80 ft. of Portland beds consisting of limestones and muddy sands. From the Lower Greensand to the Portland beds the stratigraphic groups are thinner than was expected from known thicknesses in surrounding exposures, but deeper Jurassic beds have been found in full measure. The succession, in descending order, below the Portland beds consists of: Kimeridge clays, 1102 ft.; Corallian clays with some marly and sandy limestones, 142 ft.; Oxford clays and Kellaways beds, 442 ft.; Cornbrash limestones, 18 ft.; Great Oolite limestones, 341 ft. developed in facies and thickness reminiscent of this group as exposed in the Cotswolds; Fuller's earth, 106 ft.; Inferior Oolite limestones, passing down into sandy limestones which are probably in part of Upper Lias age, 431 ft.; Upper Lias clays, 238 ft.;

a marly limestone, probably of Middle Lias age, 28 ft.; and more than 350 ft. of Middle and/or Lower Lias shales and clays in which the well is now drilling at 5792 feet.

Traces of oil have been found in cuttings and cores from Lower Purbeck, Portland, Kimeridge, Corallian and Oxford clay horizons. In deeper beds chloroform tests have yielded slight traces of oil or other bituminous matter, and some samples have shown in fluorescence under ultraviolet light, but formation tests have yielded no flow of oil.

The Henfield well drilled into Wealden clays and penetrated 920 ft. of that series. The lowest 280 ft. were dominantly sandy and have been correlated with the Hastings beds of the central and eastern Weald. No appreciable sign of oil was found in these sands and a formation test yielded a flow of water with a 35 lb. per sq. in. closed-in pressure. Beneath the Hastings beds, 520 ft. of clays, with limestones, bituminous shales and beds of anhydrite in the lower parts, have been regarded as Purbeck beds. These overlie 98 ft. of Portland beds, which are followed downwards by 1082 ft. of Kimeridge clays; 299 ft. of Corallian beds, again chiefly clays or marly limestones and without any good reservoir sands; 565 ft. of Oxford clay and Kellaways rocks; 13 ft. of Cornbrash limestones; 207 ft. of Great Oolite limestones; 118 ft. of Fuller's earth and more than 275 ft. of Inferior Oolite limestones, in which the well is now drilling at 4093 feet.

In this well cores and cuttings also yielded traces of oil, as at Portsdown, but again no flow of oil was obtained in formation tests. Of interest, though not of commercial value, was a small show of gas in the top of the Great Oolite limestones. Analysis of a sample showed it to contain approximately 73 per cent methane, 19 per cent nitrogen and 6 per cent hydrogen, but the volume of this show was so slight that it may at depth have been entirely dissolved in the salt water with which it was associated.

The original contention that oil may occur in commercial quantity in Upper Jurassic or Lower Cretaceous beds of southern England has not been completely disproved by the Portsdown and Henfield tests, though they have definitely reduced the prospects of a considerable part of the area. In so far as Upper Jurassic and Lower Cretaceous horizons are concerned, results points to lack of adequate porosity and permeability as at least one, probably the prime and possibly the sole cause of failure. Wherever samples and cores showed that there was any possibility of reservoir conditions, formation tests were made, but in the greater number of cases, no appreciable production of any fluid (oil, gas or water) was obtained. Porosity and permeability determinations of samples of Purbeck, Portland and Corallian beds without exception have given disappointingly low results.

D'Arcy Exploration Co. proposes to continue its program of testing in southern England. Another borehole is to be drilled soon on the Kingsclere anticline, near Newbury. Others will be drilled in Dorset, where geological investigations are now being pursued and where there are closed structures which, though smaller than either the Portsdown or Henfield anticlines, are closer to outcrops that are rich in oil shows.

NOTTINGHAMSHIRE, LINCOLNSHIRE AND EAST YORKSHIRE

Carboniferous beds dip eastwards from their exposures in the Pennine Hills and about the longitude of Nottingham pass beneath an unconformable sheet of Permian and younger rocks. Where exposed at surface and, more especially, in coal or lead mines and in boreholes, these Carboniferous rocks give abundant promise in the form of seepages of oil or gas and veins or pockets of bitumen of different types. These manifestations drew attention to the Carboniferous of Derbyshire and Staffordshire when Messrs. S. Pearson & Co., under contract from H. M. Government, in 1918-1921 drilled a number of test wells on anticlines closed in Coal Measures of the Upper Carboniferous. The tests failed to find any large accumulation of oil though the first well, Hardstoft No. 1, has since yielded some 2800 tons of crude oil.

Coal-exploration boreholes have shown that the Carboniferous beds, which dip eastwards below the Permian north of Nottingham, rise again further east though they do not appear again at surface west of the east coast. A borehole at Kelham found a considerable show of oil in beds believed to be of the Millstone Grit series (Upper Carboniferous). There is reason to expect that structures capable of retaining an oil accumulation may exist in Carboniferous beds below the blanket of unconformable Permian and Mesozoic strata, and the D'Arcy Exploration Co. has attacked the problem of finding and testing such structures. Surface geology is of little direct use here and several forms of geophysical investigation are being brought to bear on the problem.

A torsion balance reconnaissance is being made of the whole area over which licenses are held and additional gravitational observations have been made by gravimeter and pendulum. A magnetic survey has been made of part of the area and further work of this nature is contemplated. Seismic (reflection method) observations have been carried out over a selected traverse to test the possibilities of this method of determining structure of the hidden Carboniferous beds, particularly the Lower Carboniferous, Mountain limestone.

The problems of this area are difficult, and will be costly to solve, but if structural conditions prove favorable the region may hold a prize that is richer than the best that can be hoped for from any other part of Great Britain. So far geophysical investigation has not reached a stage at which any test drilling is justified.

NORTHEASTERN YORKSHIRE

Yet another type of oil prospect will be tested in the valley of the Esk, near Aislaby west of Whitby. Here structural conditions are simpler and it is proposed to drill a test well, during the coming summer, on the crest of a dome in which Liassic beds are exposed. The well may have to go to 4000 ft. or deeper and will explore the Magnesian limestone of Permian age. Beneath the Lias shales and limestones, which incidentally in this area contain small shows of oil, a considerable thickness of Triassic marls and sandstones, with some anhydrite and probably salt, will have to be penetrated before entering the Permian limestone, which may be as much as 1000 ft. thick.

Apart from the direct evidence of traces of petroleum in the Magnesian limestone at outcrop in Durham, the chief attraction to this prospect lies in a comparison with Permian deposition conditions in Germany. At Volkenroda, in Thuringia, commercial oil production has been obtained from limestones of equivalent age which were laid down in circumstances analogous to those of the Magnesian limestone of northeastern England.

SCOTLAND

D'Arcy Exploration Company's license in Scotland lies to the east of the Pentland Hills and includes the Cousland dome, adjacent to the D'Arcy dome. In 1920-1921, Messrs. S. Pearson & Co. drilled a test well on the latter structure and obtained more than 1700 gal. of crude oil from Lower Carboniferous beds of the oil-shale series. This well did not penetrate the full thickness of the oil-shale series. D'Arcy Exploration Co. proposes to drill at least one test to the base of that group of shales, with which are interbedded sandstones and thin limestones. As at D'Arcy, the deepest beds exposed on the Cousland dome are limestones of the Carboniferous limestone series. The borehole will penetrate about 250 ft. of this series before entering the Calciferous sandstone series, of which the uppermost member is the oil-shale group.

There is no evidence available on which to base a precise forecast of the total depth to which it will be necessary to carry the well but it is probable that by 3000 ft. the oil-shale group and at least part of the underlying cementstone group will have been penetrated. How far the well will be carried into the latter group will depend on evidence to be obtained from samples recovered. Beneath the cementstone group lie Devonian rocks in which there is no prospect of finding oil.

The oil-shale group of the Lothians contains many beds of richly bituminous shale of a type that will yield oil on distillation but not to solvents. The source of the many shows of free oil known to occur in this group of rocks is open to some doubt though there is a strong balance of opinion in favor of the hypothesis that it has been formed by distilla-

tion of the shales by igneous intrusions, of which there are many in the area.

Opinions may differ on the general assessment of Great Britain's oil prospects, where so many uncertainties must be coordinated. Some consider it probable that at least one oil field will be found, others think even that unlikely. None considers it impossible and few, if any, believe that the prospects are less favorable than those that have led to prolonged drilling in other parts of the world.

DRILLING OF PORTSDOWN NO. 1 WELL

Drilling commenced on the Portsdown well on March 30, 1936, and the depth on Jan. 16, 1937, was 5840 feet.

Equipment

The equipment installed is of the most modern type. The steam supply is obtained from four oil-field type boilers of 250 lb. working pressure, evaporating 3600 lb. of water per hour each. These boilers are fitted with turbine furnaces and superheaters. A 4-in. steam line completely lagged supplies the rig and slush pumps. Separators are installed at each offtake.

Derrick and Drawworks.—The derrick is 136 ft. high and has a 12-ft. substructure, providing a cellar, and a floor area of 675 sq. ft. The drawworks, which are of the four-speed hoist type, and fitted with a "Hydromatic" brake, are driven by a totally enclosed 12 by 12-in. engine of the piston-valve type. The 27½-in. rotary table is also totally enclosed and is of the extra heavy pattern. An 8-in. swivel and a 76-in. five-sheave block that will take a load of 200 tons are part of this modern equipment designed to drill to 12,000 ft. with safety. The heaviest available all-steel cable-tool drawworks are also installed complete with the latest chain-driven sand reel.

Slush Pumps.—The slush pumps are of the regular horizontal duplex type, are rigged up for compounding, and can be fitted with mud-end liners ranging from 7¾ to 5 in. in diameter. High-pressure cocks are used throughout to discharge manifold. As a safeguard against the possible serious consequences of losing mud into porous formation, tank storage is available for approximately 5000 cu. ft. of mud, and the slush-pump suction is coupled to these tanks.

Lighting.—In the event of a failure of the main supply a small petrol-driven generating set and portable floodlights are available on site.

Workshop.—A small workshop and forge has also been provided complete with lathe, drilling machine and grinders, portable and fixed.

Drilling

A 23-in. dia. hole was drilled to 1242 ft. and an 18-in. collar casing cemented at 1110 ft. A 17½-in. dia. hole was drilled to 2320 ft. and

15-in. casing, inserted joint, 71 lb. per ft., cemented at 2311 ft. with $24\frac{1}{4}$ tons cement. A $14\frac{1}{8}$ -in. dia. hole has been drilled to 3655 ft.; one $10\frac{5}{8}$ in. in diameter to 5529 ft. and one $7\frac{3}{4}$ in. in diameter to 5840 ft. The $10\frac{5}{8}$ or $7\frac{3}{4}$ hole can be reamed out if it is found necessary to run casing.

Drilling was started with a 23-in. rock bit and proceeded satisfactorily until a depth of 250 ft. was reached. At this stage it was necessary to pull out and the bit stuck at 203 ft., because of caving flints and chalk. All the regular methods of releasing the stuck tools failed and it was decided to try a steam jet playing around the shoulder of the reamers and alongside the bit. Three-inch cement tubing was run with a $\frac{3}{4}$ -in. side jet immediately above the plugged end of the tubing. Some time after the steam was turned on, violent eruptions of mud, due to the expansion of the steam, became apparent, the bit began to settle down under the weight of the drill pipe above it, and the tools were recovered.

Drilling with 23-in. bits was resumed and at 1110 ft. the 18-in. collar casing was set, and cemented with 9 tons of cement by the tubing method. The weight of this string of casing was 44 tons.

The cement was allowed 8 days to set and after testing the casing and cement, drilling continued with $17\frac{1}{2}$ -in. bits to 2320 ft. and the 15-in., 71-lb. inserted joint casing was cemented at 2311 ft. with $24\frac{1}{4}$ tons of cement by the plug method.

No more casing has been run up to the present time.

Coring and Testing

From 2320 ft., a $14\frac{1}{8}$ -in. dia. hole was drilled to 3655 ft. and occasional cores were taken in this region with a $10\frac{5}{8}$ core bit. When any promising formation was encountered the full hole tester was run in the pilot hole.

After testing in a pilot hole it was necessary to ream it out to the full size and invariably the reaming occupied more time than the original piloting.

Intensive coring and testing has been carried out in the $10\frac{5}{8}$ -in. and $7\frac{3}{4}$ -in. hole and the core recovery has been very satisfactory.

Up to date 16 flow tests have been made and on one occasion the tester was left in one position for 56 hours.

Drilling Bits

Practically all the well-known bits have been run in this well, and although clays have been encountered which it would be supposed drag bits would drill with ease, reasonable progress could be made only with rock bits.

In the 5840 ft. drilled, the following bits have drilled the footage given: drag bits, 1108 ft.; rock bits, 2493 ft.; core bits, 1394 ft.; other bits, 845 ft.

The careful control of weight applied to the bits has resulted in a straight hole to 5500 ft. Deviation tests were made with the acid bottle.

Petroleum Production in India in 1935*

THE world's production of petroleum in 1926 amounted to nearly 150 million long tons, of which India contributed 0.72 per cent. In 1927, this figure jumped to some 172 million long tons, of which the Indian proportion, on a practically stationary production, fell to 0.64 per cent. In 1928, there was another substantial rise in the world's production, which reached the figure of over 181 million tons. In 1929, there was another jump to over 202 million tons, but in 1930 the world's production fell to about 193½ million tons, in 1931 to about 187 million tons, and in 1932 to about 183 million tons, while in 1933 the production rose again to about 202 million tons, in 1934 to about 215 million tons, and in 1935 to 233 million tons¹. Decreases were shown by Poland, Sarawak, Egypt, Rumania and France. All other important producers showed an increase in production, by far the largest being due to Iraq, as a result of the opening of the pipe line to the Mediterranean. The United States contributed 60.9 per cent of the world's supply in 1935, Russia 10.7 per cent, Venezuela 9.4 per cent, Rumania 3.9 per cent and Iran 3.1 per cent. In 1928, India contributed 0.64 per cent, which fell to 0.60 per cent in 1929 and rose to 0.62 per cent in 1930, 0.63 per cent in 1931, and 0.64 per cent in 1932, and fell again to 0.62 per cent in 1933, to 0.60 per cent in 1934 and to 0.50 per cent in 1935; her position on the list of petroleum-producing countries fell from eleventh in 1929 to twelfth in 1930 to 1933, her place being taken by Trinidad and to thirteenth in 1934 and 1935, owing to the production by Iraq.

The production of petroleum in India (including Burma²) increased slightly from 322,025,280 gal.³ in 1934 to 322,662,336 gal. in 1935, the highest figure in the history of the industry. The increase in 1935 is due to an increase of some 4 million gallons in Assam, almost offset by a decrease of 3½ million gallons in Burma. This increase in output in 1935 was accompanied by an increase in estimated value amounting to Rs. 22,73,550 (£170,944).

* Reprinted from *Records of the Geological Survey of India, Mineral Production of India for 1935* (Heron) 71, pt. 3, by permission of the Director of the Geological Survey of India. (The report for India for the year 1936 is not yet available.)

¹ Compiled from *World Petroleum* of June, 1936.

² See page 565.

³ Imperial gallons throughout this paper.

The amount of gasoline produced from natural gas during the year was 9,717,087 gal., of which 9,309,083 gal. were produced in Burma and 408,004 gal. in the Punjab.

BURMA

Yenangyaung

The Yenangyaung field maintained its reputation of being one of the most wonderful oil fields in the world. The total production during 1935 was somewhat less than in the previous year but the resources of the field as a whole are sufficient to ensure an adequate supply of oil for many years.

At the end of 1935 there were 3030 wells producing in the field. Besides a large number of wells drilled to shallow sands, this total includes 183 hand-dug wells of which the continued existence is one of the interesting features of the field.

During the year further extensions of the producing areas on the eastern flank of the field were proved. In the southern part of the field valuable production was obtained from wells in the southern part of block 2S. and the northern part of block 4S. Within the Reserves and their Borders there were no noteworthy developments.

Satisfactory results continue to be obtained from gas drives in the leased blocks; in addition to gas drives, gas is also injected with the object of repressuring and storage. The major companies operating within the Reserves continued to cooperate in applying back pressures to youthful wells. Casing policies continue to be carefully designed to protect the oil sands against the danger of flooding by water and, in general, production methods throughout the field are characterized by a realization of the importance of the conservation of oil and gas and the prevention of waste, whether simple or underground.

Singu

In 1935 there was a slight increase in the output from the Singu field. At the end of the year the total number of producing wells was 465 as compared with 459 in December, 1934. In addition, a number of wells remained cemented above productive sands. These wells can be drilled into productive sands in a very short time and the total field production substantially increased.

In the southern part of the field a valuable producing area was proved and at the end of the year competitive drilling was in progress along the boundary between blocks 50E. and 50N.

There has been no radical change in production methods during the year under report. The fundamental principle underlying the policy of the major operating company at Singu is to make adjustments

at each well to lead to a maximum oil recovery with a minimum production of gas. Wells with high gas-oil ratios are shut in, and the casinghead gas remaining after the satisfaction of the field requirements is returned to dry gas sands for storage, or to certain areas for repressuring purposes. There is one gas drive in operation and the repressuring operations of the British Burmah Petroleum Company, Ltd., continued to give satisfactory results. During the year the Burmah Oil Company, Ltd., was actively engaged upon the construction of a training well in the River Irrawaddy to reclaim a potentially productive area. Continuous gas-lift on some wells producing from lower division sands and gas displacement pumping on wells producing from upper division sands were continued on a small scale, but production from the great majority of the wells in the field was obtained by ordinary pumping methods.

Other Districts

Yenangyat.—During 1935 there was a good deal of drilling activity at Yenangyat and, as a result, the total production from the Pakokku

TABLE 1.—*Quantity and Value of Petroleum Produced in India during the Years 1934 and 1935*

Fields	1934		1935	
	Quantity, Imp. Gal.	Value ^a , £	Quantity, Imp. Gal.	Value ^a , £
<i>Assam:</i>				
Digboi.....	63,754,262	818,542	67,886,586	871,597
<i>Burma:</i>				
Kyaukpyu.....	13,579	3,629,852 ^b	13,549	3,749,135 ^b
Minbu.....	3,873,128		3,803,949	
Singu.....	81,927,114		83,590,590	
Thayetmyo.....	685,489		916,702	
Upper Chindwin.....	3,095,245		2,788,501	
Yenangyat (including Lanywa).....	27,717,552		30,414,737	
Yenangyaung.....	137,447,963		129,810,946	
<i>Punjab:</i>				
Attock.....	3,510,948	65,995	3,436,776	64,601
Total.....	322,025,280	4,514,389	322,662,336	4,685,333

^a £1 = Rs. 13.3.

^b Estimated.

district, excluding Lanywa, shows a large increase. There was a further increase in the production from the Lanywa field during 1935. Back pressures are maintained on nearly all the wells in this model field, which is operated by the Indo-Burma Petroleum Company, Ltd. While a number of wells are pumped from a central power, the majority have

individual pumping motors. The gasoline plant was operated throughout the year and gave a satisfactory yield.

Minbu.—In the Minbu district there were, at the close of the year, 378 producing wells. The total production showed little change. Apart from routine production there was very little activity in the district.

TABLE 2.—*Imports of Kerosene Oil into India during the Years 1934 and 1935*

From	1934		1935	
	Quantity, Imp. Gal.	Value ^a , £	Quantity, Imp. Gal.	Value ^a , £
Union of Socialist Soviet Republics.	43,121,885	1,157,346	43,466,478	1,038,895
Rumania.....	8,796,256	189,286	1,013,409	21,939
Sumatra.....	6,772,813	238,048	4,689,877	152,863
Borneo.....			5,890,997	154,948
Iran.....	1,971,850	79,629	12,507,372	487,338
Java.....	1,422,981	22,159	2	
United States of America.....	2,118,839	96,149	330,992	22,183
Other countries.....	390,431	18,771	750,164	36,279
Total.....	64,595,055	1,801,388	68,649,291	1,914,435

^a £1 = Rs. 13.3.

TABLE 3.—*Imports of Fuel Oils into India during the Years 1934 and 1935*

From	1934		1935	
	Quantity, Imp. Gal.	Value ^a , £	Quantity, Imp. Gal.	Value, £
Union of Socialist Soviet Republics.....	912,132	9,846	966,060	10,848
Rumania.....	2,165,569	28,114	20	
Iran.....	77,150,970	1,026,331	98,264,798	1,227,851
Borneo.....	25,466,739	327,113	31,828,024	387,623
Other countries.....	876,027	19,505	434,945	7,585
Total.....	106,571,437	1,410,909	131,493,847	1,633,907

^a £1 = Rs. 13.3.

There was a reduction during 1935 in the total production from the Indaw field. All but one of the wells were successfully operated by the automatic gas-lift system.

Thayetmyo.—Production from the Padaukpin and Yenanna fields in the Thayetmyo district again showed an increase. Satisfactory progress was made in the drilling of the Burmah Oil Company's deep test well at

Monatkon, but as yet no discoveries of importance have come to light.

Kyaukpyu.—The output from Kyaukpyu remained at its usual low level.

ASSAM

In Assam the output of the Digboi field increased slightly. There has been no drilling in outside areas in the Assam Valley.

In the Surma Valley there was no production and prospecting operations were concentrated on the drilling of the new well at Masimpur.

TABLE 4.—*Exports of Paraffin Wax from India during the Years 1934 and 1935*

To	1934		1935	
	Quantity, Tons ^a	Value ^b , £	Quantity, Tons	Value, £
United Kingdom.....	11,419	372,688	15,366	490,704
Germany.....	1,855	58,828	205	6,579
Netherlands.....	4,778	150,905	5,103	164,288
Belgium.....	3,628	115,233	3,002	95,240
Italy.....	4,326	117,818	3,411	101,818
China.....	2,530	76,737	2,300	72,632
Union of South Africa.....	1,958	58,664	2,607	81,167
Portuguese East Africa.....	4,271	122,933	4,867	153,039
Canada.....	2,142	67,641	1,539	48,600
United States of America.....	2,751	86,520	2,322	73,453
Mexico.....	4,300	135,790	4,250	134,211
Argentine Republic.....	436	13,776	131	4,145
Chile.....	350	11,053	4,527	141,115
Australia.....	412	13,063	431	13,694
Other countries.....	1,960	61,748	3,141	98,017
Total.....	47,116	1,463,399	53,202	1,678,702

^a Long tons.

^b £1 = Rs. 13.3.

Some progress was made, but much delay arose from serious fishing jobs caused by the extremely difficult drilling conditions brought about by the nature of the formation and the exceptionally high pressures.

PUNJAB

In the Punjab the output from the Khaur field increased by over 200,000 gal. as compared with 1934. As a result of the indications from a deep test well into the underlying formations an old well was deepened to 5408 ft. in October last, giving satisfactory production. Another old well is in hand for the same objective, the depth of which at the end of the year was 4860 feet.

On the Dhulian dome a well commenced last year has been carried to 7653 ft. and drilling is still in progress. The first indication of oil was reported at 7448 ft. in September; the well was deepened carefully to 7501 ft. and at the beginning of November flowed under low pressure at 100 bbl. per day. This strike was tested for one month and production held up satisfactorily. The well was then deepened, as it was apparent that it was not yet in the limestones.

IMPORTS AND EXPORTS

There was an increase (over 4 million gallons) in the imports of kerosene, due mainly to an increase of over $10\frac{1}{2}$ million gallons from Iran and nearly 6 million gallons from Borneo, offset in part by important decreases from all other countries except Russia, the imports from which showed only a slight fall (Table 2).

There was a rise of 25 million gallons in the quantity of fuel oil imported into India, the principal change being an increase of over 22 million gallons from Iran and of over 6 million gallons from Borneo and a fall of over 2 million gallons from Rumania. Some 75 per cent of the supply was derived from Iran and some 24 per cent from Borneo (Table 3).

The exports of paraffin wax showed an increase amounting to some 6000 tons (Table 4).

Oil and Gas in Iran in 1936

(New York Meeting, February, 1937)

PRODUCING FIELDS

Masjid-i-Sulaiman Field.—During the past year, drilling activities have been limited to repair work. No new developments of importance can be recorded in production technique. Fall of dome pressure is maintained at the 1 lb. per sq. in. per annum rate mentioned in previous reports.

Acid treatment of wells is being increasingly used and for wells in fissured areas has been very successful. Such wells have been converted into first-grade producers with substantial drops in bottom-hole differential pressures. The effect of acid treatment has been to increase the flowing lives of wells so treated. The normal procedure consists of three treatments of 500 gal. commercial acid diluted 100 per cent but success has been met with fewer applications.

The policy of returning products to the reservoir has been continued. The total quantity of products returned since the policy was commenced in 1929 now amounts to approximately 30 million barrels.

Haft Kel Field.—The drilling of the main Haft Kel structure for production purposes has now been completed. Production and control wells have been completed to meet the rate of production anticipated over the next few years.

TABLE 1.—Crude Production from Masjid-i-Sulaiman and Haft Kel Fields

Year	Masjid-i-Sulaiman ^a		Haft Kel		Total	
	Tons	Barrels Equivalent to Nearest 10,000	Tons	Barrels Equivalent to Nearest 10,000	Tons	Barrels Equivalent to Nearest 10,000
1935.....	4,227,884	32,300,000	3,231,177	24,690,000	7,459,061	56,990,000
1936 (est.)..	3,640,000	27,800,000	4,474,000	34,180,000	8,114,000	61,980,000

^a Net production; i.e., excluding surplus products re-injected to reservoir.

Naft-i-Shah Field.—There are no fresh developments to report.

AERIAL SURVEY

During the year an additional 5000 sq. miles have been aerially surveyed for geological purposes.

Received through the courtesy of the Anglo-Iranian Oil Co., Ltd., London, England. Manuscript received at the office of the Institute Feb. 13, 1937.

DRILLING

The rotary system is now in general use throughout the Iranian fields. For exploratory wells in new areas it is usual to install both a cable-tool rig and rotary drawworks, since this combination provides an auxiliary drum—in the calf wheel—for pulling drill pipe in case of breakdown of the rotary gear and the sand reel is normally used for running inclinometers and other instruments. Steam drive is preferred where water supplies are available, because of its flexibility, and consists of a standard battery of four locomotive-type boilers with a steaming capacity of 3600 lb. per hour at 250 lb. per sq. in. The steam is superheated to 450° F. All feed water is treated in a softening plant to reduce boiler troubles. Steam economy is effected: (1) by usual methods of insulation and (2) by providing an independent steam-engine drive for the rotary table. For areas remote from water supply, internal-combustion engines are used, together with a hydraulic coupling between engine and pumps and engine and drawworks.

Inserted joint casing is used entirely and each joint is tested hydraulically at works to an internal pressure equal to the minimum yield point of the material less 10 per cent. In accordance with latest practice, heavy drill collars are used, normally two 30 ft. long and one 20 ft. long. Rock bits are preferred to drag bits, because of alternating hard and soft streaks.

Pressure drilling is being increasingly used, improvements, however, being limited to equipment and technique rather than to method. Valves, well-head fittings and other equipment for such wells are now being made in forged steel instead of steel castings, and shop tests of 6000 lb. per sq. in. are being specified.

The normal design of duplex slush pump with rubber-packed pistons is no longer capable of giving reliable service at working pressures of over 2000 lb. per sq. in., and double-acting ram pumps with outside packed glands are being used, designed to handle mud flush at a pressure of 3500 lb. per sq. inch.

Hydraulically operated snubbing gear has been introduced. Attention has been given to the design of blow-out preventers, all of which employ hydraulic pressure for their operation assisted by a small hydraulic accumulator.

Oil and Gas Production in Iraq during 1936

By BEN B. COX, MEMBER A.I.M.E.*

(New York Meeting, February, 1937)

THE principal event during 1936 was the sale of Mosul Oilfields, Ltd. to Mosul Holdings, Ltd., a British company with French and American participation, and the expansion of its wildcat activities to untested structures on its West Tigris concession. Mosul Holdings continued the exploration of its low-gravity Qaiyarah-Najmah-Jawan-Qasab field.

The Iraq Petroleum Company's systematic exploration and exploitation of its Kirkuk field was continued on a scientific unitized basis. Pressures and gas-oil ratios remained satisfactory. All wells were produced by flowing. A stabilization plant large enough to supply the 4,000,000-ton pipe line to the Mediterranean was completed at Kirkuk about the close of the year and only sweet oil is now being exported.

The Khanaqin Oil Co., Ltd., a subsidiary of the Anglo-Iranian Oil Co., Ltd., continued the normal exploitation of its Naft Khaneh oil field, refining and marketing through the Rafidain Oil Co., Ltd. for local Iraq market. This field lies partly on the Iraq side of the boundary and partly on the Iranian side, the latter portion being known as Naft-i-Shah. Only the Iraq side is considered in this paper.

Slightly more than 30,000,000 bbl. of crude was produced in Iraq during 1936. The I.P.C. exported all crude sold outside of Iraq and showed an increase of about 2,500,000 bbl. over the preceding year.

Crude production in Iraq for export in 1934 was 7,096,669 bbl.¹; in 1935 it was 27,014,904 bbl. and in 1936 it was 29,521,053 barrels.

Manuscript received at the office of the Institute Feb. 17, 1937. Published by permission of the Near East Development Corporation.

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¹ Converted at an average of 7.6 bbl. per ton.

Petroleum Development in Mexico during 1936

BY V. R. GARFIAS* AND R. V. WHETSEL,* MEMBERS A.I.M.E.

(New York Meeting, February, 1937)

PRODUCTION of crude petroleum in Mexico during 1936 totaled approximately 40,309,000 bbl., showing a negligible increase over the previous year. While only four producing wells were completed in the Poza Rica area in 1936, its production increased from 9,468,000 bbl. in 1935 to 13,417,000, making it the ranking producing field in Mexico. This gain in output, however, was offset by abnormal losses due to artificial curtailment mainly the result of strikes and other disturbances in the heavy-oil district of the Northern fields, which declined 2,500,000 bbl., and in the South fields (Golden Lane), where output decreased 1,500,000 bbl., while production in the Isthmus of Tehuantepec fields remained practically stationary.

Production of natural gasoline for 1936 is estimated at 800,000 bbl., or 200,000 bbl. greater than in 1935. Crude run to stills in local refineries increased about 1,000,000 bbl., totaling 31,000,000 bbl. for 1936. Exports of crude and refined products were approximately 24,400,000 bbl., or over 2,000,000 bbl. greater than in 1935, the increase representing withdrawals from storage in Mexico. Exclusive of ships' bunkers, domestic consumption increased about 1,000,000 bbl. during the year, reaching an estimated total of 15,200,000 bbl. The Mexican domestic demand for gasoline is estimated at 2,540,000 bbl. for the year, an increase of 310,000 bbl. over 1935.

In all, 70 wells were completed in Mexico during 1936, as compared to 74 in 1935 and 148 in 1934. In proven areas 59 completions resulted in 31 producers and 28 failures. Unusual results were obtained during the year over a scattered area in northeastern Mexico near the United States border, where out of eight completions six were fair-sized gas wells. A wildcat dry hole was completed in Chocoy in an attempt to extend the Northern fields to the northeast, and another in Quebrache, to the southeast of the heavy-oil district. A deep test (10,168 ft.) through the Cretaceous lime into the Jurassic was completed as a dry hole in Metlatoyuca, 9 miles southwest of the Old Alamo field on the Golden Lane.

Manuscript received at the office of the Institute Feb. 5, 1937.

* Cities Service Co., New York, N. Y.

Another wildcat in San Sebastian, 10 miles east of the Golden Lane, was also a failure.

FIELDS

Northern Fields (Heavy-oil District).—In the proven areas of the Northern fields 16 producers and 25 failures were completed as compared to 18 producers and 20 failures in 1935. A large well in the Altamire district completed early in the year revived drilling in this area, but toward the end of the year drastic salt-water invasion had almost completely halted development. Production totaled 7,884,000 bbl. in 1936, a decrease of 24 per cent from the previous year; but as it is estimated that shutdowns due to labor difficulties and strikes during the year resulted in a loss of close to 2,000,000 bbl., the normal decline was apparently only about 8 per cent.

South Fields (Golden Lane Area).—No wells were completed in the producing areas of the Golden Lane during 1936. Production of the fields declined from 9,809,000 bbl. in 1935 to 8,309,000 bbl. in 1936, a decrease of 16 per cent. The fields, however, also suffered serious curtailment during the year from labor trouble and strikes, resulting in an estimated loss of about 1,000,000 bbl., which otherwise may have been produced under normal conditions.

Poza Rica.—While only four wells, all large producers, were completed in the new Poza Rica area during the year, three of these added considerable acreage to the proven area. One well, on lot 54, extended the field $\frac{3}{4}$ mile to the south; another, on lot 26, extended it $\frac{1}{2}$ mile to the northeast; and a third, on lot 50, a mile to the east. It is estimated that the proven area at the close of 1936 totaled about eight square miles, and development has not yet defined the limits of the field to the south and east. Production in 1936 totaled 13,417,000 bbl., compared to 9,468,000 bbl. in the previous year, an increase of 41 per cent.

Isthmus of Tehuantepec.—Development in the proven areas during 1936 continued about at the same rate as during the previous year, when 11 wells, of which 9 were producers, were completed. Output also maintained an even trend throughout the year, totaling 10,576,000 barrels.

Northeastern Mexico.—While this area, which extends along the United States border from Eagle Pass to Brownsville, has yet had no commercial oil production, six fair-sized gas wells (maximum of about 4,000,000 cu. ft. daily) were completed during the year and are worthy of note. One of the gassers is near San Juan de Sabinas, State of Coahuila, about 125 miles southwest of Eagle Pass. Two were completed in Zacate, Nuevo Leon, 27 miles south of the Sam Fordyce oil field in Texas; another near Camargo, Tamaulipas, 16 miles west of Sam Fordyce. Two dry holes were completed on the Rio Bravo lease in Tamaulipas, 22 miles south of Sam Fordyce.

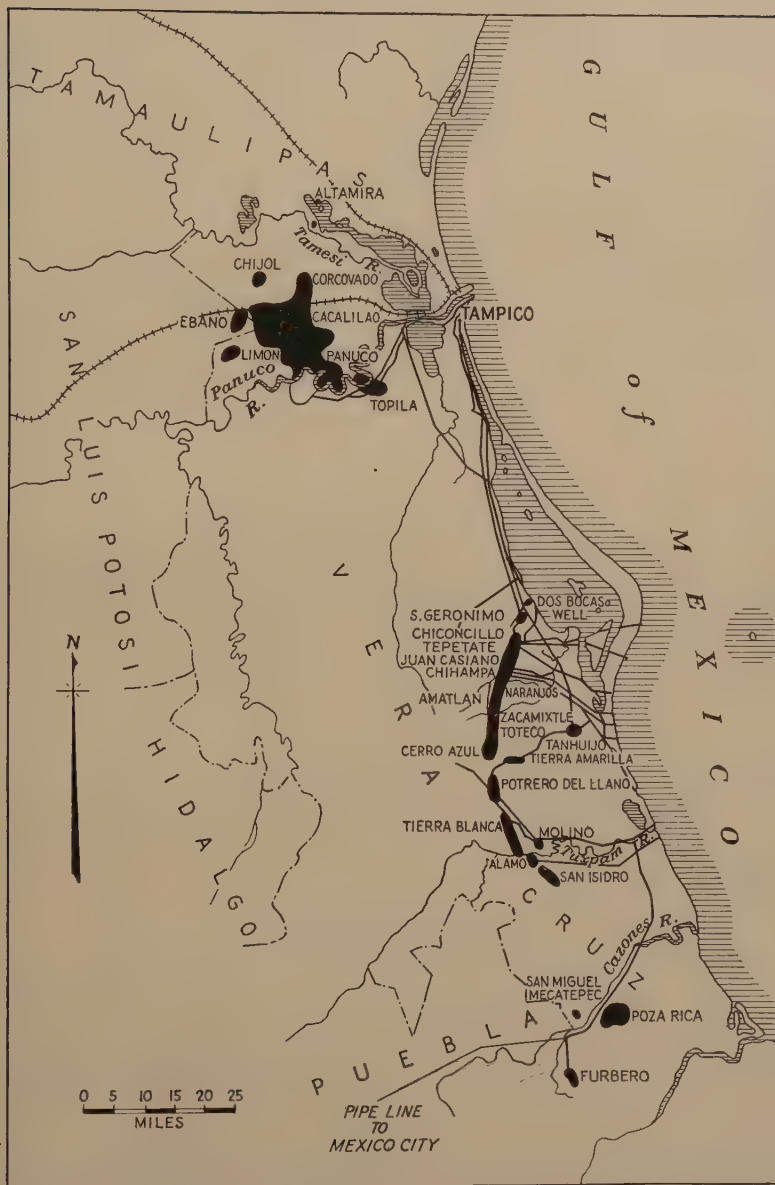


FIG 1.—NORTHERN, SOUTHERN AND POZA RICA OIL FIELDS, MEXICO.

TABLE 1.—*Production of Oil in Mexico*
U. S. Barrels

	1935	1936	Total since Discovery to End of 1936	Novem- ber 1936	Number of Pro- ducing Wells, Nov. 1936
Northern fields (11° to 14° A.P.I.).....	10,372,000	7,884,000	724,129,000	778,368	526
Southern fields, Golden Lane (20° to 24° A.P.I.).....	9,809,000	8,309,000	1,006,390,000	730,500	222
South fields, miscellaneous...	166,000	123,000	4,926,000	8,100	12
Poza Rica (33° to 34° A.P.I.)	9,468,000	13,417,000	27,591,000	892,331	16
Isthmus of Tehuantepec ^a (32.5° A.P.I.).....	10,419,000	10,576,000	80,662,000	760,484	212
	40,234,000	40,309,000	1,843,698,000		

^a Estimated.

CRUDE-OIL PRICES AND TAXES

The price of heavy Panuco crude spot cargoes f.o.b. Tampico, excluding export and production tax, dropped at the beginning of 1936 from \$1 to 75¢ per barrel. By October the price had recovered to 95¢, and at the close of the year the price had risen above \$1 per barrel. The average price in 1935 was \$1 per barrel, 80¢ in 1934, 60¢ in 1933, 44¢ in 1932, 55¢ in 1931, 60¢ in 1929 and \$1.05 in 1928.

The price of South field crude not controlled by local refineries increased slightly during 1936 to almost 45¢ a barrel at the well. At the close of 1936, Poza Rica crude was sold f.o.b. ship at Tampico for the first time, bringing an average price of about 80¢ a barrel excluding export and production tax.

TABLE 2.—*Mexican Oil Taxes*
U. S. Cash per Barrel

	December 1935	December 1936
Heavy crude.....	\$0.097	\$0.117
Light crude.....	0.158	0.188
Fuel oil.....	0.138	0.168
Refined gasoline.....	0.122	0.117
Crude gasoline.....	0.262	0.252
Refined kerosene.....	0.082	0.074
Crude kerosene.....	0.168	0.152
Lubricants.....	0.148	0.148

OUTLOOK FOR 1937

Drilling activity and production in the Northern fields and South fields (Golden Lane) are expected to further decline in 1937. It is not

expected that the rate of development in Poza Rica will increase during 1937, although new completions may further extend the proven area of the field. Production may increase in the field, but perhaps not at the same rate as in 1936. Unless again adversely affected by labor and other disturbances, as in 1936, the total output of the Mexican fields in 1937 may be about 10 per cent greater than in the previous year, or about 44,000,000 barrels.

Oil and Gas Production in the Netherlands East Indies and Sarawak*

Line Number		Age, Years to End of 1936	Total Oil Production, Bbl.			Daily Average during Nov. 1936	Average Oil Production, Bbl. per Well Daily during 1936	Total Gas Production, Millions Cu. Ft.	
			To End of 1936	During 1935	During 1936			During 1935	During 1936
1	Sarawak.....	27	72,809,825	5,052,000	4,861,000	13,920	31	3,558	3,012
2	Balik Papan and Tarakan.....	41	331,277,660	12,876,000	12,546,000	36,300	54	8,679	9,984
3	Ceram.....	40	5,031,705	288,000	349,000	1,070	26	38	18
4	Java.....	49	78,927,745	3,404,000	3,774,955	16,162	37	2,575	2,808
5	South Sumatra.....	40	205,711,251	8,451,000	26,285,460	77,796	118	11,618	12,482
6	North Sumatra.....	51	112,764,895	7,280,000	5,688,000	18,030	172	7,019	6,134
7	Total.....		806,523,081	37,351,000	53,504,415	163,278	68	33,487	34,438

1 cu. m. = 35.31 cu. ft.

Line Number	Number of Oil and/or Gas Wells							Depth, Average in Feet		Oil Production Methods at End of 1936		
	Completed to End of 1936	During 1936		At End of 1936				Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells		
		Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Gas Only	Total Producing			Flowing	Pumping	Gas-air Lift
1	541	21		23	448	2	473	340-5,280	130-5,242	14	393	41
2	1,314 _y	35	5		667	2	669	230-2,620	210-2,600	26	624	17
3	77	2			41		41	260-1,020	240-1,000	1	40	
4	1,431 _y	16	3	38	431		469	160-2,950	130-2,880	20	382	5
5	2,073 _y	51	10	69	657	4	685	290-5,400	160-5,200	76	101	208
6	727	14	2	17	105		122	300-4,140	260-4,100	38	30	37
7	6,163 _y	139	20	147	2,349	8	2,459			175	1,570	308

* Received through the courtesy of N. V. de Bataafsche Petroleum Maatschappij, The Hague, Netherlands. Manuscript received at the office of the Institute April 16, 1937.

Line Number	Producing Rock					Number of Dry and/ or Near-dry Holes to End of 1936	Deepest Zone Tested to End of 1936	
	Name	Age ^f	Character ^g	Porosity ^h , Per Cent	Struc- tures ⁱ		Name	Depth of Hole, Ft.
1	Seria- and Miri formations	Mio	SsH	18	Af	80	Miri deep shale	6,180
2	Balik Papan-Poeloe Balang and Tarakan formation	Pli + Mio	SsH, S	10-30	Af	204y	Poeloe Balang zone	5,250
3	Boela formation + Triassic	Pli + Tri	SsH	y	Af	40	Triassic	2,400
4	Mergelklei—Globigerinae— Orbitoid zones	Pli + Mio	S, SH, LS	15-35	Af	311y	Basis mergelzone	5,900
5	Palembang- and Telissa-zones	Pli + Mio + Paleogene	S, SH, SS	13-28	Af	354y	Under Telissa zone	7,550
6	Seuroela-Keutapang-Grens- klei zones	Pli + Mio	S, SH, SS	y	Af	244y	Grensklei zone	6,680

^f Footnotes to column heads and explanation of symbols are given on page 291.

Petroleum Development in Peru during 1936

BY OLIVER B. HOPKINS,* MEMBER A.I.M.E.

(New York Meeting, February, 1937)

DURING the year 1936, a new high record was established for Peruvian production, the total amounting to 17,594,689 bbl., which brought the cumulative production of the country up to 205 million barrels. The 1936 figure represents an increase of 530,288 bbl. over that of 1935. The property of the International Petroleum Co. contributed 369,577 bbl. of this increase and the Lobitos property 158,233.

Exploration work in the country was continued. The Selden Breck Co. examined a strip of the National Reserve in eastern Peru from Tambo del Sur to the Rio Pachitea. This company was granted a concession for a term of four years embracing approximately 50,000 acres near the confluence of the Rio Pachitea and the Rio Ucayali. During the year, the Peruvian Government commenced drilling a well on one of the reserved zones at Zorritos. At the end of the year, this well had reached a depth of 1300 feet.

La Brea-Parinas Estate.—Production on the La Brea-Parinas Estate of the International Petroleum Company, Ltd., reached an all-time high in 1936 of 15,126,491 bbl., an increase of 369,577 bbl. over the 1935 record. The total production from 1890 to 1936 was 163,668,014 barrels.

TABLE 1.—*Oil and Gas Production in Peru*

Line Number	Field, Department	Age, Years to End of 1936	Area Proved, Acres			
			Oil	Oil and Gas ^a	Gas	Total
1	La Brea-Parinas, Piura.....	47	y	y	y	y
2	Lobitos and Restin, Piura.....	32	y	y	y	y
3	Zorritos, Tumbes.....	53	y	y	y	y
4	Piria (Huacane), Puno.....		y	y	y	y

^a Footnotes to column heads and explanation of symbols are given on page 291.

Manuscript received at the office of the Institute Feb. 13, 1937.

* Chief Geologist, Imperial Oil Limited, Toronto, Canada.

During 1936, a total of 84,172 ft. was drilled in new wells and 7658 ft. in deepening existing wells. Twenty-two wells were deepened, and 43 new wells were completed, of which 39 produced oil, one gas and three were abandoned. At the end of the year, 2916 wells had been drilled on the estate, of which 1876 were still productive. The remaining 1040 wells represent abandoned producers or dry holes.

Drilling on this property is still done largely with cable tools. The rotary tools introduced during 1934 have shown that this equipment can satisfactorily and economically drill the various formations encountered and during the year 1936 further improvement was experienced with this equipment. In addition, a heavy-duty rotary has been secured for deeper drilling on the concession and it is proposed to install a light rotary for deepening old cable-tool wells. The cleaning out and deepening of older wells has continued to yield beneficial results.

The return of surplus gas to the producing sands in selected parts of the field was continued during the year. This practice, which was initiated in 1927, results in the recovery of a higher percentage of the production by flowing and, it is believed, in an increased ultimate yield.

TABLE 1.—(Continued)

Line Number	Total Oil Production, Bbl.				Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells								
	To End of 1936	During 1935	During 1936	Daily Average during Nov. 1936	To End of 1936	During 1935	During 1936	Maximum Daily during 1936	Completed to End of 1936	During 1936		At End of 1936					
										Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas ^b	Producing Gas Only	Total Producing	
1	163,668,014	14,756,914	15,126,491	42,234	z	z	z	z	2,916	40	3	126	y	1,740	10	1,876	
2	38,622,376	2,259,965	2,418,198	6,463	z	z	z	z	y	y	y	y	y	y	y	y	
3	3,091,211	47,522	50,000	y	z	z	z	z	y	y	y	y	y	y	y	y	
4	285,936	0	0	0	z	0	0	0	y	0	0	0	0	0	0	0	

Line Number	Depth, Average in Feet		Oil Production Methods at End of 1936						Pressure, Lb. per Sq. In. ^d		Character of Oil, Approx. Average during 1936					
	Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells					Injection into Reservoir ^c	Initial	Average at End of		Gravity A.P.I. at 60° F.			Sulphur, Per Cent	Base ^e
			Flowing	Pumping	Gas-lift	Air-lift	Miscellaneous			1935	1936	Maximum	Minimum	Weighted Average		
1	y	y	49	1,679	12		101	35	y	y	y	H.C.T. 39.3 L.C.T. 36.1	H.C.T. 38.8 L.C.T. 34.0	H.C.T. 39.1 L.C.T. 34.5	y	M
2	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y
3	y	y		y	0	0	0	0	0	0	0	0	0	0	y	0
4	y	y	0	0	0	0	0	0	0	0	0	0	0	0	y	0

^b Footnotes to table heads and explanation of symbols are given on page 291.

In an effort to arrive at a clearer idea of the potentiality of the La Brea-Parinas property, a seismograph survey was commenced in the latter half of the year.

Lobitos Property.—This property, north of the La Brea-Parinas Estate, produced during 1936 a total of 2,418,198 bbl., bringing the cumulative production to the end of 1936 to 38,622,376 bbl. Drilling on this property was continued both in the old Lobitos territory and in the northern or El Alto territory. The new oil obtained in the old Lobitos area more than offsets the natural decline in the old wells. The main success, however, took place in the northern or El Alto territory where new production amounted to nearly double that of a normal year.

Zorritos Property.—This property, operated by Piaggio and Company, is estimated to have produced approximately 50,000 bbl. during 1936.

TABLE 1.—(Continued)

Line Number	Character of Gas, Approx. Average during 1936		Producing Rock						Number of Dry and/ or Near-Dry Holes to End of 1936	Deepest Zone Tested to End of 1936	
	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Name	Age ^f	Character ^g	Porosity ^h	Net Thick- ness, Average in Feet	Structure ⁱ		Name	Depth of Hole, Feet
1	y	y	Verdun, Lomitos, Parinas	Eocene	S	y	x	AF		?	
2	y	y	Negritos, Salina	Eocene	S	y	x	AF	y	Probably Cretaceous	?
3	y	y	Terebratula, Lower Cay- erno	Eocene	S	y	x	AF	y	?	2,900?
4	y	y	Zorritos	Miocene	S	y	x	MF?	y	?	?

Oil and Gas Production in Poland during 1936

BY CHARLES BOHDANOWICZ*

(New York Meeting, February, 1937)

THE accompanying tables¹ show that in 1936 production of crude oil in Poland decreased very slightly (Tables 1 and 5), by about 1 per cent, and that gas production increased by about 11 per cent. As in preceding years, drilling (Tables 1, 2 and 3) was devoted principally to extension of oil fields in the Jasło district (fields 1, 5 and 7) and, in a lesser degree, of those in the Stanisławów district (field 27). Production of crude oil is being sustained in a large measure by the deepening of old wells; besides a total number of 183 new wells completed (Table 3) about 152 wells were deepened, and in a general way the results of deepening were better than those of new wells drilled.

Reserves of "proved land" have not increased as far as crude oil is concerned, but a notable extension of gas fields² was attained in Daszawa (field 25) and in the Roztoki area (field 5). In the sub-Carpathian zone gas fields have been proved in the vicinity of Kalusz, Kosów, and in the northwestern sector of that zone, between Tarnów and Leżajsk. The gas horizons of Daszawa occur in the Upper Tortonian, those of Kosów in the Lower Tortonian (Middle Miocene). Exploratory drilling has been performed near Kalusz, and has been commenced near Kosów and in the Tarnów area. The Kosów gas approaches the "wet" type.

A possible gas reserve with a volume of 4,000,000,000 cu. m. (141,000,000,000 cu. ft.) has been calculated, for an area of about 5 sq. km. of the Daszawa field, on the basis of production obtained and of decreases in pressure and their distribution. The fields of Roztoki and Strachocina (No. 12) have not yet supplied sufficient data for a calculation of reserves, which might possibly be estimated at 2,000,000,000 cu. m. (70,000,000,000 cu. ft.).

Manuscript received at the office of the Institute Feb. 12, 1937.

* Professor of Economic Geology, Warsaw, Poland.

¹ Figures in Table 1 for 1935 have been corrected according to last data available, and figures for 1936 may be subject to slight corrections after final data become public. It should be noted that in 1936 the fields of Rypne (27) were transferred to the mining district of Stanisławów, and that this change is reflected in the figures for the districts of Stanisławów and Drohobycz outside of Boryslaw, respectively.

Detailed material covering the numerous oil fields of the Jasło district has been obtained through the collaboration of A. Nieniewski, M. E., of Krosno.

² K. Tolwiński: Le problème des réserves de gaz naturel en Pologne. *Ann. de la Soc. Géol. de Pologne* (1936) 12.

Gasoline production (Table 7) has declined by about 9 per cent, even if the 1000 tons of gasoline obtained in Roztoki under the name of "white crude oil," which are not included in statistics as such, are taken into account. The decline in the total production of gasoline is due to the drop in the volume of casinghead gas in the Boryslaw field, in spite of the fact that the number of wells producing gas exclusively have increased in that field (140 wells in 1936 vs. 121 in 1935).

TABLE 1.—*Oil and Gas Production in Poland*

Line Number	Field, County	Age, Years to End of 1936	Area Proved, Acres	
			Oil	Oil and Gas ^a
	JASLO DISTRICT			
1	Lipinki, Libusza, Kryg, Kobylanka Dominikowice Wojtowa, Gorlice.....	71	1,075	
2	Korczyn, Biecz, Gorlice.....	39	65	
3	Sekowa, Ropice Ruska, Gorlice.....	64	100	
4	Harklowa, Jaslo.....	66	130	
5	Roztoki-Sadkowa, Dobrucowa, Bialkowka, Brzeszowka, Jaslo.....	27	889	445
6	Mecinka, Jaszczew, Jaslo-Krosno.....			
7	Potok-Toroszowka, Krosno.....			
8	Krosno-Krosienko, Krosno.....	45	48	
9	Bobrka-Rowne-Rogi-Wietrano, Krosno.....	48	78	
10	Iwoniec-Klimkowa, Krosno.....	78	225	
11	Ropianka, Krosno.....	46	?	
12	Strachocina-Gorki, Brzozow-Sanok.....	68	30	
13	Zmiennica-Turzepole, Brzozow.....	8		
14	Starawies-Brzozow-Humniska-Grabownica, Brzozow-Sanok.....	40	67	
15	Weglowka, Krosno.....	40		321
16	Lubatowska-Wulka, Krosno-Sanok.....	49	148	
17	Mokre-Tarnawa, Sanok-Lesko.....	48	275	
18	Total Jaslo (with others)	24	25	
	DROHOBYCZ DISTRICT		3,029	766
19	Rajskie-Polana-Lipie Bystre, Lesko.....	50	50	
20	Lodyne-Wankowa-Ropienka Paszowa-Stankowa, Lesko.....	50	568	
21	Strzelbice, Sambor.....	55	62	
22	Opaka, Drohobycz.....	40	25	
23	Boryslaw (deep "skiba"), Drohobycz.....	42		3,700
24	Schodnica-Urycz, Drohobycz-Stryj.....	64	1,110	
25	Daszawa, Stryj.....	15	1,815	3,700
26	Total Drohobycz			
	STANISLAWOW DISTRICT			
27	Rypne-Duba-Perehinako, Dolina.....	49	1,500	
28	Bitkow, Nadworna.....	37	1,080	
29	Pasieczna, Nadworna.....	56	400	
30	Majdan-Rosulna, Kalusz.....	47	220	
31	Sloboda Rungurska, Kolomyja.....	61	120	
32	Kosmacz, Kolomyja.....	36	40	
33	Total Stanislawow.....		3,280	
34	Other fields.....			
35	Total.....			

^a Footnotes to column heads and explanation of symbols are given on page 291.

The cubic meters of gas treated for gasoline vapors were as follows: in the mining district of Jaslo, about 19,000,000; in Boryslaw, about 135,000,000 and in Stanislawów, about 48,000,000. The average yield of gasoline amounted to 49 grams per cubic meter for Jaslo; 234 grams for Boryslaw and 95 grams for Stanislawów, which corresponds approximately to 0.60, 2.65 and 1.05 gal. per 1000 cu. ft., respectively.

The increase in the production of ozocerite deserves attention (Table 8). In 1936 production once more reached a considerable volume,

TABLE 1.—(Continued)

Line Number	Area Proved, Acres		Total Oil Production, Bbl.				Total Gas Production, Millions Cu. Ft.			
	Gas	Total	To End of 1936	During 1935	During 1936	Daily Average during Nov. 1936	To End of 1936	During 1935	During 1936	Maximum Daily during 1936
1		1,075	4,342,024	189,366	233,100	682	x	48	50	0.149
2		65	348,400	30,465	29,674	89	x	63	63	0.192
3		100	741,275	17,109	17,316	49	x	x	3.5	x
4		130(?)	1,640,842	62,934	60,902	170		39	36	0.102
5	375	1,709	176,564	29,600	40,404	126	47,688	2,965	3,136	10.663
6			188,108	21,204	38,850	96		671	395	1.933
7			5,339,818	93,940	125,302	333		194	143	4.818
8			1,917,792	38,720	31,372	89		x	6	8.7
9			5,431,386	71,240	54,751	158		x	164	159
10		225				4.7				0.511
11		?	x	1,702	1,776	5.3				
12	494(?)	30		2,590	2,146		x	23	22	0.072
		494(?)					780	155	124	5.0
13		67	663,560	17,538	17,020	46		37	35	0.106
14		321		97,450	83,768	237	x	385	321	0.981
15		148	1,974,263	30,380	27,158	72		23	24	0.070
16		275	1,047,840	31,894	37,932	73	x	25	24	0.062
17		25	55,290	3,960	6,105	17				
18	869	4,664	24,154,882	711,825	779,256	(+9.4%)2,400	53,294	4,690	4,606	
19		50	81,290	5,085	14,933			4		
20		568	6,002,200	180,175	173,382			55	y	y
21		62	585,830	19,110	21,460			12	y	y
22		25	133,090	3,360	2,960				y	y
23		3,700		2,116,992	2,000,000	(-5.5%)5,400	187,895	4,865	y	y
24		1,110		330,995	355,866	962		192	y	y
25	1,250	1,250					42,208	5,250		
26	1,250	6,765		2,655,717	2,568,601	7,100	230,103	10,378	11,815	
27		1,500	2,171,230	149,030	128,760		y	432	y	y
28	100	1,180	6,073,264	206,250	174,046	496	y	1,376	y	y
29	150	550		25,000	42,376		y	132	y	y
30		220		21,360	20,438					
31		120		13,120	11,914					
32		40	210,900	3,957	3,922					
33	350	3,630		418,717	341,456	990	32,000	1,940	2,242	
34		x		x	x				412	
35		15,059	240,932,744	3,812,970	3,689,313 3,774,000	(-1%)	315,000	17,008	19,075	(+11%)

as the result of a larger demand for this raw product in foreign markets (France, Germany, Czechoslovakia).

Measures taken by the Government in 1936 toward the creation of a fund to subsidize explorative drilling³ have attained, so far, but slight results, in the shape of about 2200 m. drilled from subsidies supplied from that fund but applied exclusively to deepening wells in old fields.

TABLE 1.—(Continued)

Line Number	Number of Oil and/or Gas Wells							Depth, Average in Feet		Oil Production Methods at End of 1936						Pressure, Kg. per Sq. Cm.			
	Completed to End of 1936	During 1936		At End of 1936					Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells					Injection into Reservoirs	Average at End of		
		Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas ^b	Producing Gas Only	Total Producing			Flowing	Pumping	Gas-lift	Air-lift	Swabbing		Initial	1935	1936
1	860	56		14	478		1	479	1,500		440			38			2-25		
2	49	3		1	37			37	960		37								
3	166	6		31		87		87	720	760	65			22					
4	273	4		4	134		1	135	1,280	720	129	3	8	5					
5	33	5		1		6	25	31	3,280	2,700	4	1	4	1	110		110		
6	16	1	2			8	6	14	3,120	2,700	3		3	2	110	45	38		
7	248	5	4	11		76	1	77	2,300	2,100	3	72		1	35	15	15		
8	108			1	44			44	1,800			44			5-10	5-10			
9	245	1		7	37	52	3	91	2,130			60		29	60	?	?		
10	x	1		7	18			18	700			18							
11	60	1		4	17		1	18	1,640			13		4					
12	3						3		2,590 to 4,050	3					80-93		80-93		
13	61	1	1	2	36			36	1,480		29			7					
14	104	2		8	60			60	2,300		34	3	5	18	50	5	5		
15	223	1		3	81			81	1,050		81								
16	83	3		11	10	53		53	1,480		42			11					
17	18	1			10			10	1,800		9			1					
18	2,558	105						1,274											
19	61	7	2	42	15		1	16	1,310		15								
20	431	16		20	365			365	1,310		365								
21	73			9	40			40	660		40								
22	15			1	5			5	1,970		5								
23	1,288	6		235		525	140	665	4,270		33			492					
24	779	23			520			520	1,480		518			2					
25	19	1		2			18	18	2,300						852	539			
26	2,666	53						1,629											
27	225	9			117			117	2,625		73			44					
28	175	6				96		96	3,610		4		7	85					
29	192	1				31		31	660 to 4,700		10			21	2,272	1,420			
30	101	1			67			67	1,150		48		2	17					
31	300				51			51	985		51								
32	10				10			10	1,920		10								
33	1,003	17						371											
34	x	7																	
35	6,224	183						3,274 (3,310)											

³ *Trans. A.I.M.E.* (1936) 118, 491.

The problem of prospecting drilling upon the plains of northern and western Poland⁴ in the Paleozoic formations still remains a theoretical consideration, although in 1936 several new but real facts have been published regarding emanations of gas and manifestations of crude oil in those districts. The matter of a broad prospecting program upon those areas attains now actual importance, but it would require radical amendments of the present mining law in regard to prospecting for crude

TABLE 1.—(Continued)

Line Number	Character of Oil, Approx. Average during 1936				Character of Gas, Approx. Average during 1936		Producing Rock					
	Gravity A.P.I. at 60° F		Paraffin, Per Cent	Base ^a	B.t.u. per Cu. Ft.	Gasoline Grams per Cu. M.	Name	Age ^f	Character ^g	Porosity ^h	Net Thick- ness, Aver- age in Feet	Structure ⁱ
	Maximum	Minimum										
1	32	38	34	P	1,124		Ciezkowice I, II	Eoc	S	18.7-21.3	80	AM
2	33	43	39	A	1,124		Ciezkowice I, II	Eoc	S		120	diapir
3	29	40	35	A		200	Magura facies	Cre	S		40	A
4	21	27	27	A			Krosno beds	Olig	S		150	overthrust
5	40	42	40	A	1,011	10-100	Ciezkowice II, III	Eoc, Cre	S	12.2	245	diapir
6	42	42	4.0	P		25-50	Ciezkowice II, III	Eoc, Cre	S		198	diapir
7	39	51	42	A	1,124	150	Ciezkowice II, III	Eoc, Cre	S		80	diapir
8	29	34	32	M		150	Ciezkowice I, II	Eoc	S		190	diapir
9	32	38	34	A, P		225	Ciezkowice I-III, IV	Eoc, Cre	S		160	A
10			35	A			Krosno beds	Olig	S		132	A
11	29	31	31	A			Magura facies	Cre	S		60	A
12				A	1,124	13	Czarnorzecki	Cre	S			A
13			33	P			Ciezkowice I	Eoc	S		100	A
14	37	47		A, P	1,067	150	Ciezkowice I, II, III	Eoc, Cre	S	19.6 18.4 20.5	200	diapir.
15	27	30	29	A			Czarnorzecki	Cre	S		100	AM
16			29	A		150	Ciezkowice I-III	Eoc, Cre	S		100	A
17	35	45	44	A			Krosno beds (lower)	Olig	S		?	Af
18						49						
19	38	45	42	P, A			Krosno beds (lower)	Olig	S		?	Af
20	30	39	34	P			Krosno beds (lower) and Menilite series (upper)	Olig	S		40-50	diapir
21	31	33	32	P			Jamna beds	Cre	S		45	A
22	42	44	43	P			Eocene beds	Eoc (lower)	S		50	A
23	31	36	33	P	1,461	234	Boryslaw sandstone (IV)	Olig (Eoc, Cre)	S	10.0 15.0 17.4	IV = 30-120	AF
24	29	39	36	AP			Jamna beds	Cre	S		150	A
25							Gas beds	Mio	S	25	100	A
26												
27	33	39	36	P			Kliwa beds	Olig	S		60	AF
28	34	48	44	AP			Kliwa beds	Olig	S		15-30	AF
29	38	56	45	AP	1,067		Kliwa beds, platy beds	Olig Cre	S		15-30	AF
30	29	37	34	A			Eocene beds	Eoc	S		60-80	A
31	35	37	37	P			Jamna beds	Cre	S		80	A
32	30	33	32	A			Inoceramus beds	Cre	SH		40	A
33						35						
34												
35												

⁴ Trans. A.I.M.E. (1935) 114, 526.

oil and gas, and would necessitate geophysical surveys accompanied by legal safeguards for the possible development of the oil industry upon the new tracts situated outside of the Carpathian province.

TABLE 2.—*Total Meters Drilled, Poland*

Year	Jaslo	Outside Boryslaw	Boryslaw Fields	Stanislawow	Total
1936	49,921	30,800	8,500	19,100	108,321
1935	37,682	23,166	10,638	12,530	84,016 (86,122)
1934	38,080	19,480	8,219	8,824	74,603 (77,933)
1933	32,382	19,418	7,582	7,519	66,901
1932	25,267	17,690	8,063	7,458	58,478
1931	28,666	20,749	14,444	10,653	74,512
1930	38,551	30,251	28,616	19,180	116,598

TABLE 3.—*Number of Wells Completed*

Districts	1935		1936	
	New Wells	Deepened Wells	New Wells	Deepened Wells
Jaslo				
Producing.....	87	83	105	57
Nonproductive.....	12	9		
Outside Boryslaw				
Producing.....	47	10	53	24
Nonproductive.....	5	1		
Boryslaw				
Producing.....	10	19	8	69
Nonproductive.....	1	5		
Stanislawow				
Producing.....	14	14	17	2
Nonproductive.....	1	4		
Total				
Producing.....	158	126	183	152
Nonproductive.....	19	19	15	
Average daily production per well, kg.....	2142	1732	1800	3410

TABLE 4.—*Number of Producing Wells*

Year	Jaslo	Outside Boryslaw	Boryslaw Fields	Stanislawow	Total
1936	1274	964	665	371	3274
1935	1149	1025	650	253	3280 (other fields—203)
1934	1195	1046	632	248	3121 (with other fields)
1933	1117	1009	603	245	2974
1932	1065	990	598	246	2899
1931	1027	963	574	250	2814
1930	951	952	562	250	2715

TABLE 5.—*Total Oil Production, Poland*
In cars (10,000 kg.)^a

Year	Jaslo	Outside Boryslaw	Boryslaw	Stanislawow	Total
1936	10,856	7,856	27,037	5,251	51,000
1935	9,908	9,429	28,598	3,541	51,476
1934	9,953	9,141	30,426	3,268	52,788
1933	9,645	9,588	32,514	3,320	55,067
1932	9,582	9,043	33,029	4,014	55,668
1931	9,765	9,491	39,070	4,702	63,028
1930	8,535	8,561	44,334	4,847	66,277

^a One 10-ton car = 74 barrels.TABLE 6.—*Total Gas Production, Poland*
Thousands of Cubic Meters

Year	Jaslo	Outside Boryslaw	Boryslaw	Stanislawow	Total
1936	142,200	213,200	121,400	63,500	540,300
1935	136,476	168,507	137,390	43,036	485,409
1934	121,200	149,722	154,516	43,300	468,738
1933	97,664	142,978	176,972	44,597	462,211
1932	86,347	115,811	186,764	48,008	436,030
1931	86,719	127,549	211,763	47,792	473,823
1930	75,432	120,034	242,612	48,428	486,506

TABLE 7.—*Gasoline Production, Poland*
Kilograms

Year	Jaslo	District Drohobycz	Stanislawow	Total
1936	3,460,498	27,618,500	4,577,406	35,656,404
1935	3,831,056	32,887,608	2,763,744	39,482,408
1934	4,436,585	33,349,333	2,952,171	40,738,069
1933	4,033,312	34,924,813	3,020,301	41,978,426
1932	2,521,915	33,257,716	3,053,045	38,832,676
1931	1,455,932	36,140,120	3,384,970	40,981,022
1930	197,240	34,903,905	3,392,505	38,493,650
Number of gasoline plants in				
1934.....	7	16	4	27
1935.....	6	14	5	25
1936.....	6	13	5	24

TABLE 8.—*Ozocerite Production, Poland*
Kilograms

Year	Boryslaw	Districts Stanislawow Dzwiniacz-Starunia	Total
1936	343,593	99,299	442,892
1935	300,945	68,163	369,108
1934	89,138	67,027	156,165
1933	326,648	39,368	366,014
1932	308,815	279,887	588,702
1931	110,050	152,253	262,303
1930	681,255	220,401	901,656

Oil Development in Rumania during 1936

BY IONEL I. GARDESCU*

(New York Meeting, February, 1937)

RUMANIA produced during 1936 some 62,500,000 bbl. of oil. Of this production, 99 per cent comes from an area running east and west along the southern foothills of the Carpathian Mountains just north of Bucharest. This almost rectangular area measures 20 by 40 miles and is located in the districts of Dambovița and Prahova between the cities of Targoviște to the west and Mizil to the east. The remainder of the production is about evenly divided between the oil fields north and east of Mizil in the Buzău district and those to the north on the eastern flanks of the Carpathian Mountains in the district of Bacău. The Transylvanian Basin to the north and west of the Carpathian Mountains has produced to date only dry gas from its numerous salt domes.

BUCȘANI FIELD

The Bucșani oil field produced 15,600,000 bbl., or 25 per cent of the total production of Rumania in 1936. Bucșani is a deep-seated salt dome 7 miles south of the old Moreni oil field. A slight surface doming, not dissimilar to the topography observed on some of the oil fields of the Californian basin, called attention to the area. It is the southernmost oil field and, together with the deep-seated and prolific Boldesti field, points to the great oil possibilities of the deep-seated domes along the northern edge of the Rumanian plains south of the Carpathian foothills.

The Government is the principal owner of the oil and gas subsurface rights in the areas south of the foothills. The acquisition of leases by the operating oil companies may be made either by application for an exploration permit, the company being assigned part of the acreage in case of successful wildcatting, or, if the area has already been declared as proven territory, through competitive bidding. A block of 164 acres was auctioned recently for \$200,000, or \$1200 per acre.

The largest producer in the Bucșani oil field is the Steaua Romana, which produced 39.5 per cent of the total for the field. The Steaua Romana is a post-war company and 50 per cent of its shares are owned by the British Steaua and the Steaua Française and the other 50 per cent by a group of Rumanian banks and by the Government. The Colombia,

Manuscript received at the office of the Institute Feb. 17, 1937.

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whose largest stockholder is Desmarais Frères, produced 22.5 per cent. The Unirea, controlled by the Phoenix Oil and Transport Co., produced 17 per cent. The Astra Romana, Shell subsidiary, produced 10.5 per cent.

TABLE 1.—*Rumanian Petroleum Statistics*¹

Principal Fields	Crude Oil Production, Tons, 1936		Increase or Decrease 1935-1936, Average per Month	Percentage Increase or Decrease 1935-1936, Average per Month	Meters Drilled, 1936	Well Situation at End of 1936			Stocks of Crude End of 1936, Tons	
	Total	Average per Month				Hand Wells, Producing	Wells			
							Re-pair	Drilling		Producing
Bucsanl.....	2,176,726	181,394	+ 127,794	+ 238.5	139,452		3	14	80	10,812
Gura Ocnitel.....	1,890,766	157,564	- 61,436	- 28.0	22,632		6	6	254	19,214
Ochiuri.....	369,325	30,777	- 1,823	- 5.5	6,486		1	4	71	3,420
Rasvad, Viforata and Teis Aninoasa.....	561,711	46,809	- 27,591	- 37.0	27,718		4	1	72	8,778
Others.....	1,512	126	- 94	- 42.5	2,346	2		1	1	49
Total Dambovit district.....	5,000,040	416,670	+ 36,850	+ 9.5	198,634	2	14	26	478	42,273
Boldesti.....	1,405,150	117,096	- 11,904	- 9.0	45,961			8	82	13,262
Moreni.....	737,069	61,422	+ 2,222	+ 4.0	9,355		6	2	242	14,128
Pisouri.....	510,022	42,502	+ 7,002	+ 19.5	20,456		1	5	79	17,859
Ceptura.....	320,602	26,717	- 2,783	- 9.5					62	5,956
Margineni.....	17,142	1,429	+ 1,429	+ 100.0	13,304			2	5	203
Aricesti.....	153,544	12,795	- 5,705	- 31.0	6,067				12	4,020
Campina.....	33,071	2,756	+ 66	+ 2.5					68	3,451
Runcu, Bustenari, Bordeni, Soorteni, Chiciura.....	259,899	21,658	- 4,142	- 16.0	3,753	41	3	3	480	7,517
Baioi Tintes.....	88,585	7,382	+ 462	+ 6.5	8,614		5	5	50	1,935
Others.....	79,732	6,644	+ 3,384	+ 104.0	20,646			10	12	1,099
Total Prahova district.....	3,604,816	300,401	- 9,969	- 3.0	128,156	41	15	35	1,092	69,430
Bacau district.....	48,381	4,032	- 138	- 3.5	852	100	7	2	161	2,848
Buzau district.....	49,817	4,152	- 148	- 3.5	147	4		1	85	1,888
Transylvania district.....					220					
Total Rumania.....	8,703,054	725,255	+ 26,595	+ 4.0	328,009	147	36	64	1,816	125,587 ²
From private lands.....	5,153,180	429,430	+ 52,770	+ 14.0	188,218	147	27	33	1,272	} 242,026
From state lands.....	3,549,894	295,825	- 26,175	- 8.0	139,791		9	31	544	

¹ Source: *Moniteur du Pétrole Roumain* (Feb. 1, 1937).

² Stock in pump stations.

The Concordia, which is controlled by the Petrofina, a subsidiary of the Campagnie Financière Belge des Pétroles, produced 8 per cent. Many shares of the Petrofina are held by the Forapetrol, which is controlled by Baron J. L. V. Allard. Baron Allard represents the Association Franco-Belge des Pétroles in the Campagnie Française des Pétroles. It was through the Petrofina that the French Government made an agreement to buy from the Rumanian Government its oil royalties.

GURA-OCNIȚEI FIELD

The Gura-Ocniței oil field is north of the Buceșani, and is a western extension of the old and prolific Moreni oil field. The structure is a piercement type salt anticline extending continuously from west to east through the Gura-Ocniței, Moreni, Bana and Piscuri oil fields. The main producing formation, which is the same as that encountered in Buceșani and practically all other fields south of the Carpathian Mountains, is from the Meotie sands of lower Pliocene age. There are also some secondary accumulations of oil in the upper Pliocene sands on some of the piercement type domes.

TABLE 2.—*Rumanian Average Daily Crude Production*
Barrels of 42 Gallons

1936	All Rumania	Bucșani	Rest of Rumania
January.....	171,750	34,100	137,650
February.....	170,500	36,900	133,600
March.....	173,000	40,300	132,700
April.....	179,000	43,700	135,300
May.....	184,500	48,200	136,300
June.....	190,500	51,400	139,100
July.....	186,000	52,000	134,000
August.....	185,250	52,800	132,450
September.....	180,000	46,900	133,100
October.....	173,000	43,900	129,100
November ¹	170,650	43,200	127,450
December ¹	167,400	41,700	125,700

¹ Source: *Moniteur du Petrole Roumain* (Feb. 1, 1937).

Thirteen and a half million barrels of oil was produced by the Gura-Ocniței field, or 21.8 per cent of the total production of Rumania for 1936. Among the larger producers were the Concordia (52 per cent); the Italian governmental company, Prahova, (15.5 per cent); Colombia (9 per cent); the Standard of New Jersey subsidiary, Romano-Americana (9 per cent); Steaua Romana (5 per cent); and Unirea (4.5 per cent).

BOLDESTI FIELD

Boldesti field, north of the city of Ploesti, is a deep-seated salt structure of the Buceșani type. During 1936 it produced 10,130,000 bbl., or 16 per cent of the total production of Rumania. The potential of the field is much greater but is held down by the few companies that control the entire area. The largest producer is the Astra (Shell) with 54.5 per cent, followed by the Unirea with 22 per cent. The Astra also leads in the production of the Moreni oil field, having produced one-third of the 8,250,000 bbl. produced by that field during 1936.

ECONOMIC CONSIDERATIONS

The oil companies in Rumania are greatly handicapped in their development for more than one reason. The Government controls the pipe lines and, aside from an old kerosene pipe line running from Ploesti to Constantza by the Black Sea, has delayed every effort made by the industry to build adequate pipe lines to the Black Sea. The Government also controls the railroads. During the part of the year that agricultural products are not being shipped, the rail transportation of oil, though inefficient, provides for a substantial and steady income to the railroads.

Oil companies find it difficult to pay their dividends to stockholders outside of Rumania and, for that reason, most companies apply their earnings to depletion of capital, keeping themselves in very liquid form as well as delaying the payment of heavy taxes.

Oil companies have found it increasingly difficult to import drilling equipment, and some of the companies, such as the Concordia, have built their own plants for the manufacture and repair of such equipment.

The greatest handicap that is confronting the oil companies is the lack of proven reserves. The Government owns practically all of the oil rights in the Rumanian plains in which are located the deep-seated structures that represent the greatest known potential reserve of Rumania. The Government, however, has been offering the areas it controls only on a piecemeal basis, which greatly retards not only the development of such areas but also geophysical prospecting and necessary wild-cattling.

OIL RESERVES

Professor Macovei, Director of the Geological Institute of Rumania, estimates the proven and partly depleted oil areas of Rumania to be 7000 acres with an estimated reserve of 200,000,000 bbl. of oil. The probable oil area is estimated at 13,000 acres with an estimated reserve of 200,000,000 bbl. The possible productive area that may extend practically all along the Carpathian Mountains is estimated at 500,000 acres. These areas should also include the Transylvanian Basin with its 44 domes whose area is estimated at 1,500,000 acres. No wells have as yet been drilled to the Oligocene and Eocene sandstones underlying the Miocene gas-bearing formations.

Professor Macovei's figures, based on an estimated recovery per acre of 30,000 bbl., may be somewhat optimistic in the light of recent development west of the present producing areas. Several wildcat wells proved that the Meotie sands, which are the main producing formation, are very shaly to the west of Bucşani. This field has not come up to early expectations. Several wells high on the structure had to be shut down because of the high gas-oil ratio and to the east of the field the Romano-Ameri-

cana encountered water within the limits of what was considered proven territory.

An interesting point of controversy arose when one of the companies completed a well producing a good grade of gasoline. The well has been flowing steadily for several months. The neighboring operating companies asked that the well be shut down because of its high gas-oil ratio. This was done but the fact remains that at the prevailing reservoir pressure all of the gas is present in liquid form.

Russian Oil Industry in 1936

BY BASIL B. ZAVOICO,* MEMBER A.I.M.E.

(New York Meeting, February, 1937)

DURING 1936 the Russian oil industry made very satisfactory progress and, while not all difficulties of organization have been ironed out, the country is now assured of a supply of petroleum products in sufficient quantities and of quality demanded by modern motor equipment. The year 1937 promises to better by a wide margin the good showing of 1936.

The statistics given in this paper for the first time take into consideration the varying gravities of crude oils of the several Russian oil fields instead of using a flat conversion factor of 7 bbl. per metric ton. It was found from the detailed study that the generally used average conversion factor should be increased from 7 to 7.25 bbl. per metric ton, the figure varying, of course, with the gravity of oil in the individual fields.

Crude-oil production during 1936 is estimated at 201,500,000 bbl. as compared with 182,970,000 bbl. produced in 1935, an increase of 9.4 per cent. The greatest increase was again recorded in the Baku district, which increased its production by 10.9 per cent, from 141,257,000 bbl. in 1935 to 158,300,000 in 1936. Grozny district maintained its production at a level of about 23,000,000 bbl., but its old fields continued to decline and production was sustained by the development of newer fields.

A great advance was made in drilling speeds and the total footage in 1936 reached 6,694,200 ft. as compared with 4,926,600 ft. drilled in 1935, an increase of 26.4 per cent. In older deep fields, producers were being completed at over 8000 ft.—a great depth for Russian drillers but two years ago. Several major discoveries were made in 1936.

Northeast Caucasus.—Izberbash, east from Grozny and on the Caspian Sea, was the outstanding discovery, the initial production of the discovery well being around 3000 bbl. per day from about 5000 ft. The importance of the field is due to the large area of the structure, half of which, however, is under the sea, and also to its strategic location on the shores of the Caspian and near a trunk pipe line to the Grozny refining center. An active development program is being pursued in Izberbash and its 1937 production quota is set at 7,500,000 bbl.

Achi-Su field, near Izberbash, also discovered during 1936, while not as prolific as Izberbash, is thought to cover a very large area and the small

Manuscript received at the office of the Institute Feb. 17, 1937; revised April 23, 1937.

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TABLE 1.—*Crude Oil Production in Russian Oil Fields from 1821 to 1936*
Thousands of Barrels

Year	Trans-Caucasus, Baku and Georgia $F^1 = 7.28$	North Caucasus Grozny $F = 7.19$	Northwest Caucasus		Central Asia	
			Maikop $F = 7.33$	Kuban $F = 7.33$	Turkmenneft $F = 7.41$	Sredazneft $F = 7.20$
1821-1871	2,307.8	54.6		266.8		
1872	190.0	5.0		2.2		
1873	484.8	3.6		4.4	4.4	
1874	593.3	4.3		11.7	11.9	
1875	762.9	3.6		27.9	169.7	
1876	1,330.1	5.0		8.1	45.2	
1877	1,801.8	6.5		11.7	23.7	
1878	2,394.4	9.3		5.1	24.5	
1879	2,872.0	15.8		8.1	34.8	
1880	2,499.2	19.4		11.0	34.8	
1881	4,777.9	16.5		4.4	28.9	
1882	5,955.0	15.1		40.3	12.6	
1883	7,152.7	13.7		44.7	5.2	
1884	10,631.7	9.3		97.5	30.4	
1885	13,717.0	8.6		135.6	6.7	0.7
1886	13,658.0	10.8		124.6	8.9	0.7
1887	16,943.5	13.7		125.3	98.6	1.4
1888	21,734.4	19.4		150.3	34.8	0.7
1889	23,649.8	33.1		166.4	34.8	
1890	27,206.1	44.6		217.0	34.8	
1891	32,749.8	53.2	2.2	128.3	21.5	0.7
1892	33,911.0	36.7	2.9	166.4	23.7	0.7
1893	39,171.5	985.7	2.2	61.6	25.2	
1894	35,005.2	616.9	1.5	145.9	10.4	0.7
1895	45,545.1	3,343.4	1.5	159.8	10.4	1.4
1896	46,483.5	2,768.9	1.5	167.9	11.1	0.7
1897	50,588.0	2,161.3	2.9	170.1	10.4	0.7
1898	58,339.7	2,097.3	0.7	142.9	41.5	0.7
1899	62,123.9	2,914.8	2.9	99.7	34.8	0.7
1900	71,821.6	3,610.1	0.7	31.5	44.5	1.4
1901	79,925.7	4,086.8	2.9	31.5	74.1	1.4
1902	76,466.9	4,025.7	2.2	47.6	64.5	2.9
1903	71,738.6	3,957.4	2.2	34.5	36.3	56.2
1904	74,122.0	4,933.8	1.5	16.1	72.6	242.6
1905	49,387.5	5,193.3	11.0		106.0	509.8
1906	54,246.9	4,580.7	10.3		79.3	381.6
1907	57,779.9	4,664.9	13.9	5.9	92.6	327.6
1908	56,894.7	6,137.4	18.3	5.9	155.6	100.1
1909	60,446.6	6,725.5	90.9	7.3	222.3	205.2
1910	59,926.8	8,729.4	162.7	5.9	956.6	294.5
1911	54,872.3	8,859.5	944.1	6.6	1,615.4	280.1
1912	56,776.7	7,710.6	1,103.9	12.5	1,578.3	166.3
1913	55,523.8	8,679.8	583.5	64.5	959.6	236.9
1914	51,698.2	11,600.3	492.6	46.9	607.6	220.3
1915	54,464.6	10,390.3	937.5	77.0	548.3	252.7
1916	57,468.3	12,108.0	264.6	101.2	422.4	207.4
1917	48,382.9	12,619.9	305.7	125.3	363.1	155.5
1918	24,936.9	2,993.9	451.5	140.0	363.1	120.2
1919	27,220.1	4,316.2	358.4	86.5		126.0
1920	21,221.2	6,247.4	115.1	29.3		123.8
1920-21	17,889.1	8,651.0	240.4	74.8	34.1	110.2
1921-22	21,930.3	10,331.3	310.1	89.4	53.4	120.2
1922-23	26,012.9	10,809.4	321.8	56.4	42.2	136.1
1923-24	30,800.2	11,727.6	384.8	68.2	38.5	133.9
1924-25	34,487.5	14,572.0	484.5	118.7	45.2	159.1
1925-26	40,666.8	17,341.6	457.4	92.4	84.5	203.8
1926-27	50,204.3	21,726.0	490.4	109.2	74.1	171.4
1927-28	55,746.6	25,713.6	651.6	123.1	57.8	282.2
1928-29	63,812.8	31,945.2	1,023.3	120.2	65.2	100.8
1929-30	74,860.2	43,550.5	3,324.9	101.9	86.0	544.3
Sp. quarter 1930	21,484.0	15,802.2	381.2	29.3	39.3	442.8
1931	96,229.2	57,979.4	3,889.3	175.9	103.0	354.2
1932	89,089.0	55,432.7	6,666.6	151.0	251.2	424.8
1933	111,964.9	34,959.2	4,330.6	124.6	1,146.3	424.8
1934	140,088.3	24,231.7	6,877.0	118.0	118.6	1,154.9
1935	141,257.5	22,793.0	8,642.1	114.3	2,487.5	
1936 ²	158,300.0	23,000.0	³	³	³	
Total.....	2,904,725.9	588,027.4	44,367.8 ⁴	5,249.1 ⁴	13,922.8 ⁴	8,585.6 ⁴
Before 1920-21.....	1,729,902.3	157,461.0	5,891.8	3,581.7	9,195.9	3,997.1
After 1920-21.....	1,174,823.6	430,566.4	38,476.0 ⁴	1,667.4 ⁴	4,726.9 ⁴	4,588.5 ⁴

¹ F , conversion factor from metric tons into barrels according to average crude gravities in each district.² Preliminary estimates.³ Detailed figures not available.⁴ Not including 1936 production.

TABLE 1.—(Continued)

Year	Emba <i>F</i> = 6.97	Crimea <i>F</i> = 7.28	Sakhalin <i>F</i> = 6.82	Ural Bashkiria <i>F</i> = 7.19	Ural Kama <i>F</i> = 6.97	Total
1821-1871		1.5				2,630.7
1872						197.2
1873						497.2
1874		2.2				623.4
1875		2.2				966.3
1876		0.7				1,389.1
1877		0.7				1,844.4
1878						2,433.3
1879						2,930.7
1880						2,564.4
1881						4,827.7
1882						6,023.0
1883						7,216.3
1884						10,768.9
1885		3.6				13,872.2
1886		0.7				13,803.7
1887						17,182.5
1888						21,939.6
1889		0.7				23,884.8
1890		3.6				27,506.1
1891		2.2				32,957.9
1892		0.7				34,142.1
1893						40,246.2
1894						35,780.6
1895						49,061.6
1896						49,433.6
1897						52,933.4
1898						60,622.8
1899						65,176.8
1900						75,509.8
1901						84,122.4
1902						80,611.2
1903						75,771.9
1904						79,202.2
1905						54,940.4
1906						59,420.3
1907						62,945.5
1908						63,539.5
1909						67,592.7
1910						69,986.6
1911	125.5					66,717.9
1912	116.4					67,578.5
1913	819.7					66,797.2
1914	1,901.4					66,583.9
1915	1,899.3					68,537.3
1916	1,774.6					72,359.4
1917	1,783.6					63,833.2
1918	1,016.2					30,109.0
1919	185.4					32,322.1
1920	211.2					27,944.4
1920-21	400.1					27,415.5
1921-22	933.3					33,771.6
1922-23	927.7					38,280.6
1923-24	874.7					44,014.2
1924-25	1,358.5					51,202.5
1925-26	1,520.2					60,296.8
1926-27	1,766.9					74,530.0
1927-28	1,741.1		120.0		4.2	84,237.6
1928-29	1,875.6		509.5		39.0	99,137.9
1929-30	2,381.6		215.5		11.2	125,135.8
Sp. quarter 1930	584.1		911.8		43.2	38,647.6
1931	2,270.1		1,247.4	33.1	41.8	162,146.2
1932	1,721.6		1,339.4	147.4	100.4	155,077.2
1933	1,368.9		1,649.1	450.1	85.0	155,835.9
1934	1,684.0		1,632.0	2,917.7	55.8	175,726.6
1935	1,912.6					182,967.4
1936 ^a				6,780.0		201,500.0
Total.....	33,154.3 ^a	18.8 ^a	7,624.7 ^a	10,328.3	380.6 ^a	3,629,805.3
Before 1920-21.....	9,833.3	18.8				1,919,881.9
After 1920-21.....	23,321.0 ^a		7,624.7 ^a	10,328.3	380.6 ^a	1,709,923.4
1937 plan.....						250,000.0
1937 probability.....						215,000.0

initial production of its oil wells is more than compensated by the shallow depth. Seven wells already completed have initial production ranging from 70 to 200 bbl. from depth of around 2400 ft. Achi-Su is also favorably located in regard to supply depots and crude-oil transportation facilities.

Southeast Caucasus.—On the Apsheron Peninsula the Puta district saw several outstanding developments in 1936, a notable discovery having been made in Shangar, while Kergez and Kizil-Tepe, discovered prior to 1936, were being actively developed. In older famous fields of Baku district deeper penetration uncovered additional reserves of major magnitude.

South of Apsheron Peninsula a major field was discovered at Pirsagat early in 1936, and a second producer was completed in October, producing 2500 bbl. from 4500 ft. This field has been faced with a difficult problem of heaving shales, but as the year closed several wells were drilled through the heaving-shale section and the Soviet engineers reported that the problem was on the way to solution.

North Caucasus.—Several small fields were discovered in Maikop and Kuban districts, outstanding being Asphalt Mountain and Kutaiski in Maikop and Adagum and Keslerovo in Kuban.

Ural-Permian Basin.—Between Stavropol and Sizran, on the Volga River, very promising results were obtained in the Samarski Luki range of hills, a well-known major anticlinal fold. While commercial production has not yet been found, results suggest a major province. Ishimbaevo field, in Bashkir Steppes, was actively developed during 1936 and its production reached 6,780,000 bbl., as compared with 2,917,000 bbl. in 1935. Ishimbaevo's 1937 output should reach 12,000,000 to 15,000,000 barrels.

Summary.—Thus it is estimated that during 1936 the Soviet oil industry blocked out between 400,000,000 and 500,000,000 bbl. of new crude oil at easily accessible points, or at least twice the volume of its production in that year.

Refining.—During 1936 Russian refineries ran to stills 178,000,000 bbl., or 14.8 per cent above 1935 runs, when 152,000,000 bbl. were processed. The refinery facilities of U. S. S. R. are being actively expanded, with particular stress on cracking equipment. It is estimated that during 1936 about 68,000,000 bbl. of various stocks were charged to Soviet cracking stills, producing some 27,000,000 bbl. of gasoline, or a recovery of 39.8 per cent—a major improvement over the showing of the preceding years, indicating that Soviet engineers are finally becoming familiarized with the various processes. Polymerization plants are also being built and planned in order to provide aviation with high-octane motor fuel.

Exports.—During the first 11 months of 1936 exports of petroleum products from U. S. S. R. declined 17.0 per cent in volume and 12.8 per

TABLE 2.—*Drilling in Russian Oil Fields from 1871 to 1936*
Thousands of Feet

	Trans-Caucasus, Baku and Georgia	North Caucasus, Grozny	Northwest Caucasus, Maikop and Kuban	Emba	Central Asia		Sakhalin	Ural District	Crimea	Total
					Turkmenneft	Sredazneft				
1871	0.3									0.3
1872										8.9
1873	8.9									9.8
1874	9.8									5.2
1875	5.2									9.5
1876	9.5									5.6
1877	5.6									17.4
1878	17.4									23.3
1879	23.3									9.2
1880	9.2									15.7
1881	15.7									21.3
1882	21.3									16.4
1883	16.4									36.4
1884	36.4									41.3
1885	41.3									46.3
1886	46.3									67.6
1887	67.6									58.7
1888	58.7									95.1
1889	95.1									103.7
1890	103.7									140.1
1891	140.1									82.0
1892	82.0									76.7
1893	76.4	0.3								83.6
1894	83.3	0.3								144.3
1895	142.7	1.6								215.2
1896	196.2	19.0								278.2
1897	278.2									426.9
1898	401.6	25.3								605.0
1899	571.2	33.8								623.7
1900	580.4	43.3								582.1
1901	528.9	53.2								311.0
1902	280.5	30.5								388.1
1903	343.5	44.6								472.8
1904	435.4	37.4								284.8
1905	249.0	35.8								374.4
1906	336.0	38.4								480.3
1907	427.5	52.8								489.8
1908	426.5	63.3								463.3
1909	380.6	82.7								473.4
1910	354.3	87.6	31.5							501.0
1911	341.2	71.5	83.7	4.6						639.6
1912	436.4	118.8	73.2	11.2						907.6
1913	563.7	206.4	101.4	30.2		5.9				820.6
1914	467.5	278.9	42.7	31.5						655.6
1915	413.4	178.5	38.1	25.6						594.8
1916	388.8	159.5	18.0	28.5						362.2
1917	228.0	127.0		7.2						18.4
1918	17.7			.7						43.3
1919	43.3									24.6
1920	20.3	4.3								19.4
1920-21	11.2	5.9	1.6	.7						62.7
1921-22	49.2	11.2	1.6	.7						228.6
1922-23	165.7	55.1	6.2	1.6						404.2
1923-24	254.6	132.9	11.5	5.2						597.8
1924-25	389.8	187.0	7.9	12.8						944.5
1925-26	658.8	245.7	16.4	18.7						1,252.2
1926-27	830.4	343.8	28.5	40.0						1,188.1
1927-28	855.0	245.1	38.4	43.0	1.3					1,463.5
1928-29	1,051.6	288.1	44.3	59.1	1.0	10.5				1,919.3
1929-30	1,328.1	349.8	60.7	97.1	7.2	22.3	8.9	36.4		559.4
Sp. Quarter 1930	386.8	95.1	21.7	34.5	1.3	7.5	1.0	11.5		2,320.4
1931	1,493.8	400.3	126.3	160.8	6.6	45.6	26.6	60.4		2,443.3
1932	1,610.0	331.7	160.8	146.3	9.5	60.7	57.7	66.6		2,741.3
1933	1,773.7	451.1	154.9	119.1	8.2	63.7	60.0	110.6		4,117.3
1934	2,648.4	800.2	216.2	154.2	17.1	80.1	68.2	128.6	4.3	4,926.6
1935	3,181.3	853.1	339.6	157.5	24.3	63.7	74.2	226.7	6.2	6,694.2
1936	1	1	1	1	1	1	1	1	1	
Total.....	26,514.7 ²	6,590.9 ²	1,625.2 ²	1,190.8 ²	77.5 ²	379.0 ²	314.3 ²	640.8 ²	10.5 ²	44,037.9
Before 1920-21.....	9,826.3	1,794.8	388.6	139.5		5.9				12,155.1
After 1920-21.....	16,688.4 ²	4,796.1 ²	1,236.6 ²	1,051.3 ²	77.5 ²	373.1 ²	314.3 ²	640.8 ²	10.5 ²	31,882.8
1937 plan.....										8,200.0
1937 probability....										8,000.0

¹ Detailed figures not available for 1936.² Not including 1936 footage.

cent in value as compared with the corresponding period of 1935—an interesting development. The generalized table (Table 3) illustrates well the trend of change.

TABLE 3.—*Exports from U. S. S. R.*
Barrels

	11 Months 1935	11 Months 1936	Change, Per Cent
Crude oil.....	753,438	1,081,409	+43.5
Gasoline.....	5,164,281	3,392,829	-34.3
Kerosene.....	2,938,160	2,874,464	- 2.2
Lubricating oils.....	1,673,471	1,434,752	-14.3
Gas and fuel oils.....	10,330,560	8,535,105	-17.4
	20,859,910	17,318,559	-17.0

CONCLUSION

It should be stressed that in 1937 the Russian oil industry will begin to approach the American production and refining standards, though it will probably take the country another five years or longer to fully catch up with American engineering methods and practices.

The rapid industrialization of U. S. S. R. will continue in 1937 to make greater and greater demands for petroleum products and hence exports will continue to decline.

Petroleum Development in Venezuela during 1936

By C. C. McDERMOND*

(New York Meeting, February, 1937)

IN reviewing petroleum development in Venezuela during the year 1936, it is well to bear in mind certain factors that affected progress, although not directly connected with the oil industry itself. At the start of the year, when the present Federal Administration took over the reins of government, reaction against the former regime resulted in some popular uprisings. Although these were entirely political in character, they were not without their effect on the oil industry itself.

Such popular agitation really ended with a short general strike in Caracas, Maracaibo and other cities during June, these strikes being based on demands for certain changes in government policies. The strikes were duly investigated and their motives taken into consideration by the executive power or by Congress, and during the year many of the civil, political and administrative laws have been revised.

In June and December, however, it was necessary to suspend activities in drilling and production work, particularly in the Lake Maracaibo Basin area. In June a strike caused a five-day shutdown in the main producing fields and on Dec. 14 labor difficulties resulted in a shutdown that continued to the end of the year, which necessitated suspension of all drilling and production in the Lake Basin area and curtailment of shipments to deep-water terminals. Actually, the strike lasted for a period of 42 days, until Federal intervention brought the dispute to a close with minor wage increases to workers but with no loss of initiative or independence on the part of the oil companies. Operations in eastern Venezuela were not affected by the labor disturbances, production and exports having been reduced in December only in the Lake Basin fields.

WELL COMPLETIONS

On Jan. 1, 1937, a total of 3384 wells had been completed throughout Venezuelan fields, as compared with 3094 on Jan. 1, 1936. Of these wells, 2005 were producers. The 290 completions effected during 1936 were by the following operating companies: Lago Petroleum Corporation, 123 completions; Dutch Shell group, 104; Standard Oil Company of Venezuela, 46; Mene Grande Oil Co., 15; British Controlled Oilfields, Ltd., 2.

Manuscript received at the office of the Institute Feb. 13, 1937.

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Drilling during the year was confined to the following main producing fields: La Rosa, Lagunillas, Mene Grande, Media, Cumarebo and Quiriquire. Wildcat drilling was carried on in eastern Venezuela and will be covered in another section of this report.

No completions were effected during 1936 in the following fields: El Mene and Hombre Pintado (B.C.O.); La Paz and Concepcion (V.O.C.); Tarra, Los Manueles and Rio de Oro (C.D.C.); Totumo, Las Palmas, Pedernales and Orocuai (S.O.V.); Urumaco (R.P.V.); Guanoco (N.Y.B.); Mene de Acosta (T.O.V.) and Netick (O.O.C.).

Abbreviations of company names used throughout this paper are as follows:

B.C.O., British Controlled Oilfields, Ltd.	N.Y.B., New York & Bermudez Co.
V.O.C., Venezuelan Oil Concessions, Ltd.	T.O.V., Tocuyo Oilfields of Venezuela.
C.D.C., Colon Development Co., Ltd.	O.O.C., Orinoco Oil Co.
S.O.V., Standard Oil Company of Venezuela.	L.P.C., Lago Petroleum Corporation.
R.P.V., Richmond Petroleum Company of Venezuela.	C.P.C., Caribbean Petroleum Co.
	M.G.O., Mene Grande Oil Co. (formerly Venezuela Gulf Oil Co.).

Of the 290 completions, only four wells were dry holes or junked—one at Media field, one at Cumarebo and two at Quiriquire.

As in previous years, Lagunillas field contributed most to 1936 drilling activity, with 175 completions; followed by La Rosa with 44, Quiriquire with 38, Mene Grande with 22, Cumarebo with 9 and Media with 3 completions.

However, only 150 of the 290 wells completed during 1936 were actually producing on Jan. 1, 1937. The difference is due to the fact that a number of new wells were closed in immediately after completion because of lack of facilities; particularly where step-out drilling was carried on and where no flow lines or pickup stations had yet been provided to permit production. Also, many wells that were flowing naturally before showed declining output to a point where pumping was considered necessary, and several were closed in pending arrival and installation of the necessary pumping units.

At close of 1936, twenty-five strings of tools were in operation in eight fields as follows: La Rosa, 3; Lagunillas, 8; Mene Grande, 4; Media, 1; Rio Tarra, 2; Cumarebo, 1; Quiriquire, 5; Pedernales-Amacuro, 1. Additional strings were in use on wildcats; viz., 7 on exploratory wells of the Standard Oil Company of Venezuela and 3 in operations of the Mene Grande Oil Co., both in eastern Venezuela.

A concise summary of drilling operations in Venezuela from start of operations in 1917 up to and including Jan. 1, 1937, is given in Table 1. A total of 3747 wells had been drilled in producing fields (including the new Amacuro field, which is actually a part of the Pedernales field). Of

these, 3147 were producers, 368 having since been abandoned, and 232 wells were dry or junked holes.

TABLE 1.—*Summary of Drilling Operations, Venezuela*
Year Ending Jan. 1, 1937

Fields	Area Proven, Acreage	Oil Wells Drilled				Abandoned Producers	Total	Average Depth of Hole Drilled to Date, Ft.	Active Drilling Operations End Jan. 1, 1937		
		Prior to Jan. 1, 1936		During 1936					Oil	Expl. ¹	Gas
		Producers	Dry or Junked	Producers	Dry or Junked						
Ambrosio.....	28,070	1,034	21	44	}	69	1,168	2,360	3		
La Rosa.....											
Punta Benitez.....											
Lagunillas.....	48,075 ²	811	10	175		21	1,017	3,360	8		
Mene Grande.....	5,980	268	16	22		14	320	2,380	4		
El Mene.....	850	227	58			121	406	1,000			
Media.....	55	16	12	2	1	13	44	3,500	1		
Hombre Pintado.....	150	4	1				5	1,600			
La Paz.....	255	31	4			2	37	1,310			
Concepcion.....	910	101	1			1	103	1,718			
Rio Tarra.....	985	67	13			10	90	2,310	2 ⁵		
Rio de Oro.....	400	2	2				4	1,630			
Los Manuales.....	255	13	2			2	17	4,020			
Guanoco.....	150	15	9			10	34	1,298			
Mene de Acosta.....	75	40	41			67	148				
Totumo.....	300	10	2			2	14	2,359			
Las Palmas.....	50	7	6			5	18	2,750			
Cumarebo.....	470	70	12	8	1	13	104	1,625	1		
Quiriquire.....	10,250	133	9	36	2	9	189	3,000	5		
Urumaco.....	100	4	2			3	9	3,383			
Netick.....		2					2				
Pedernales ³	130	2	4	2		2	10	4	1		
Orocual.....	975	1	3			4	8	3,000			
Total.....	98,485	2,858	228	289	4	368	3,747		25		

¹ Exploratory or wildcat operations.

² Tia Juana included (7210), also Bachaquero (4750).

³ Includes Amacuro.

⁴ Amacuro: 5380.

⁵ Deepening.

Proven Acreage.—In the first column of Table 1 is given an estimate of the proven acreage in each field. These figures are based on latest available data and include extension of the various fields during the year 1936. The estimated total of 28,070 acres for the La Rosa area includes the Ambrosio-La Rosa-Punta Benitez fields. These three have been gradually joined by drilling into one common productive field and production and export totals for the La Rosa district include figures for the three formerly separate fields. The total of 48,075 acres estimated for Lagunillas includes Tia Juana and Bachaquero fields as well, and is in comparison with 45,500 acres a year ago. There is also a small increase

shown in the Mene Grande field, total acreage proven to date being 5980 acres. Very little proving up was accomplished during the year in the Quiriquire field or Cumarebo fields, most drilling having been in areas already proved up.

PRODUCING FIELDS AND METHODS OF PRODUCTION

In Venezuela fields, 2005 wells were producing oil at the end of 1936, which is an increase of 150 producers for the year. Output was taken during 1935 and 1936 as follows:

Method	1935	1936	Increase	Decrease
Flowing natural.....	513	570	57	
Gas or air-lift.....	314	273		41
Pumping.....	1028	1162	134	
Total.....	1855	2005	150	

Table 2 shows in detail the total number of wells in each category and field pertaining to the respective operating companies as of Jan. 1, 1937. Table 3 gives completion compilation in Venezuelan fields for each year from 1914 to 1936 inclusive.

PRODUCTION OF CRUDE OIL

The production of crude oil in Venezuela reached a new high during 1936, when a total of 155,228,982 bbl. was reached—in contrast with the 1935 total of 148,528,790 bbl., or an increase of 6,700,192 bbl. over 1935 and almost $17\frac{1}{4}$ million barrels over 1934 production. It is worthy of note that an estimated $5\frac{3}{4}$ million barrels output was lost because of shutdown in activities during the period of the December strike in the Lake Basin district. The 1936 total might well have exceeded 160 million barrels.

The fields contributing to the 1936 output with names of operating companies are given in Table 4. Their respective percentages of participation in the 155,228,982-bbl. total were as follows: Lagunillas, 55.4 per cent; Quiriquire, 15.0; La Rosa, 13.7; Mene Grande, 10.0; others, 5.9.

In the Lagunillas field, the Lago Petroleum Corporation contributed about 46 per cent to the field total, the Venezuelan Oil Concessions about 34 per cent and the Mene Grande Oil Co. 19 per cent, whereas in the La Rosa field percentages were Lago 40 per cent, V.O.C. 40 per cent and M.G.O. 20 per cent.

The increase of 6,700,192 bbl. over 1935 total output of 148,528,790 was due to the flush production obtained from new drilling in Lagunillas and Quiriquire, and to the increased yield from 134 new pumping units,

TABLE 2.—*Producing Fields, Venezuela, 1936*
Showing Method of Producing¹

Fields	Lago				M.G.O.				V.O.C.				C.P.C.				C.D.C.				B.C.O.				S.O.V.				T.O.V.				Summary			
	A ² B		C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D				
La Rosa.....	215	94	121	181	18	163	272	28	66	178																					668	140	66	462		
Lagunillas.....	337	122	73	142	199	11	188	283	91	22	170																				819	224	95	500		
Concepcion.....							78	3	75																						78	3	75			
La Paz.....							4	1	3																						4	1	3			
Mene Grande.....																																				
Tarra.....																																				
Los Manuales.....																																				
El Mene.....																																				
Media.....																																				
Hombre Pintado.....																																				
Cumarebo.....																																				
Quiriquire.....																																				
Pedernales.....																																				
Orocual.....																																				
Amacuro.....																																				
Las Palmas.....																																				
Mene de Acosta.....																																				
Total.....	552	216	73	263	380	29	351	637	123	88	426	133	58	70	5	34	15	19	96	2	42	52	160	127	33	13	2005	570	273	1162						

¹ Status shown is actually as of Dec. 1, 1936, because strike declared Dec. 14, 1936, caused restriction of production operations, many wells being shut in as of Jan. 1, 1937.

² A, number of wells; B, flowing; C, gas and air-lift; D, pumping.

³ Estimated. No reports available.

TABLE 3.—*Completion Compilation for Producing Fields in Venezuela Jan. 1, 1937*

Field	Ambrosio		La Rosa			Punta Benitez			Lagunillas			Mene Grande	El Mene	Media	Hb. Pintado
	Lago	V.G.O.	V.O.C.	Lago	V.G.O.	V.O.C.	Lago	V.G.O.	V.O.C.	Lago	V.G.O.	V.O.C.	B.C.O.	B.C.O.	B.C.O.
1914															
1915						1						2			
1916												3			
1917						2						1			
1918															
1919															
1920															
1921												1			
1922															
1923															
1924						1									
1925															
1926				4	2	7									
1927	1	1		26	20	22									
1928	10	10		27	30	77									
1929	21	7		28	20	45									
1930	4	10		46	22	36									
1931	10	21		4	55	170									
1932		18		1	39	85									
1933						28									
1934				5	2	27									
1935				16											
1936				21	1										
				25	2	2									
Total.....	46	67	2	203	193	513	81	14	1	379	231	382	285	27	5

¹ Includes Tia Juana wells.

TABLE 3.—(Continued)

Field	La Paz	Concep- cion	Tarra and Manueles	Oro	Totumo	Las Palmas	Cumarebo	Quiri- quire	Peder- nales	Orocual	Amacuro	Urumaco	Guanoco	Mene de Acosta	Total
Year	V.O.C.	V.O.C.	C.D.C.	C.D.C.	S.O.V.	S.O.V.	S.O.V.	S.O.V.	S.O.V.	S.O.V.	S.O.V.	R.P. Co. V	N.Y. & B. Co.	T.O.V. Ltd.	
1914				2									7		9
1915			1		1								2		8
1916			1										1		4
1917			1												1
1918			2												3
1919															3
1920															1
1921	2														11
1922	1		1												6
1923															26
1924	1		1											1	56
1925	6	18	2										2	1	164
1926	14	28	6										2	2	305
1927	4	19	9	2									3	6	371
1928			7		1	3		2				1	3	5	417
1929			15		10	2		8				2	2	12	595
1930	5	16	31			6		23				2	2	26	428
1931	2	19	7			2	5	14				1		17	114
1932			3				14	6						8	46
1933		2	4				24	14						2	121
1934			4				26	37	1	4					231
1935			4				13	39	1					1	174
1936							8	36			2				290
Total.....	35	102	95	4	12	13	90	179	2	4	2	6	24	81	3384

most of which were installed in the Maracaibo Lake Basin district. The rapid expansion of pumping facilities was due in large part to the reworking of many old wells and others that had previously been minor producers by air-lift or gas-lift. The increase in output from the Bolivar coastal fields of La Rosa and Lagunillas can be attributed also to the expansion in drilling of the three major operators towards the end of the year, which was due mainly to offset drilling.

TABLE 4.—*Summary of Production, Venezuela, in 1936*

Fields (Over 1 Yr. Old)	Production, Bbl. of 42 Gal.			Number of Wells Producing by Various Methods			Age of Field, Years	Average Gravity of Oil, A.P.I.
	Prior to 1936	During 1936	Cum. to End Jan. 1, 1937	Flow- ing	Gas and Air-lift	Pump- ing		
Ambrosio.....								
La Rosa.....	271,238,194	21,287,809	292,526,003					
Punta Benitez.....								
Lagunillas.....	584,530,971	85,997,554	670,528,525	224	95	500	10½	16.70
Mene Grande.....	158,281,177	15,428,454	173,709,631	58	70	5	23	1
El Mene.....	20,153,930	583,931	20,737,861		37	51	16½	37.20
Media.....	1,109,145	227,456	1,336,601	2	5		6	37.50
Hombre Pintado.....	187,651	15,248	202,899			1	8	36.67
La Paz.....	3,362,523	183,820	3,546,343	1		3	14	21.60
Concepcion.....	17,041,760	1,111,693	18,153,453	3		75	12	35.40
Rio de Oro.....							21	30.20
Tarra.....	25,053,632	3,412,569	28,466,201	7		19	20½	2
Los Manueles.....	13,624,352	825,450	14,449,802	8			10	3
Guanoco.....	1,855,805		1,855,805				23	10.49
Mene de Acosta.....	820,192	24,290	844,482			13½	10	4
Totumo.....	141,636		141,636				21½	20.98
Las Palmas.....	163,896	10,285	174,181				8	34.00
Cumarebo.....	13,919,703	2,794,092	16,713,795	35		6	6	4
Quiriquire.....	49,592,986	23,176,855	72,769,841	89		27	8	16.00
Pedernales.....	45,257	4,076	49,333				3	15.00
Orocual.....	17,340	9,951	27,291				3	13.00
Amacuro.....		135,439	135,439	3			1	18.70
Urumaco.....	205,072		205,072				10½	34.00
Netick.....	55,118		55,118				4	27.00
Total.....	1,161,400,340	155,228,982	1,316,629,312	570	273	1,162		

¹ 28° and 17.45°.

² 30.2° and 22.6°.

³ Production prior to Jan. 1, 1931 included with Tarra.

⁴ From 41° to 50°.

⁵ Estimated.

The daily average for the year 1936 was 424,123 bbl. compared with 406,914 bbl. in 1935. The monthly daily averages varied from a low of 400,345 bbl. in June 1936 to a high of 455,825 in October. December production of 8,300,718 bbl. averaged only 267,765 bbl. daily, the sharp decline being due to shutdown of producers in the Lake Basin area because of labor disturbances.

In Table 4, a summary of production is given. In 1936 production was being taken at the end of the year from a total of 570 wells flowing naturally, 272 by air or gas-lift, and 1162 pumpers—a total of 2005 wells.

The Mene Grande field of the Caribbean Petroleum Co. is the oldest, being a producer for 23 years, La Rosa is second with 19 years, and El Mene third with $16\frac{1}{2}$ years, followed by Lagunillas with $10\frac{1}{2}$ years. The youngest is the Amacuro field, of the Standard of Venezuela in eastern Venezuela, which was opened during 1936. It is, however, really part of the three-year old Pedernales field, the name being changed because the Venezuelan Seaboard Oil Co. participates in production from this field.

Gravities of the oil produced vary from a low of 10.49° A.P.I. gravity in the Guanoco field to a high of from 41° to 50° A.P.I. in the Cumarebo field. At Amacuro the average gravity of oil, based on two completions effected during the year, is 18.7° A.P.I.

Table 5 shows the monthly production of crude oil in each Venezuelan field throughout the year, giving names of respective operators and showing the yearly total of 155,228,982 bbl. for 1936 for all fields and companies. To this total the Lagunillas field contributed 55.4 per cent, Quiriquire field 15.0 per cent, La Rosa field 13.7 per cent, Mene Grande 10.0 per cent and the others 5.9 per cent.

Table 6 shows the yearly totals of production from 1917 up to and including 1936. The aggregate grand total of 1,316,629,322 bbl. of crude had been produced up to Dec. 31, 1936.

The 1936 high output of 155,229,982 bbl. was seconded by 1935 production of 148,523,790 bbl. The order in which the various fields participated in the total accumulated production over the period 1917–1936 was as follows: Lagunillas, 51 per cent; La Rosa area, 22; Mene Grande, 13; Quiriquire, 6; others, 8.

EXPORTS OF CRUDE OIL FROM VENEZUELA

Shipments of crude from all Venezuelan fields during 1936 reached the record total of 149,140,963 bbl., compared with 140,410,240 bbl. during 1935, or an increase of 8,730,723 bbl. Such exports during 1936 averaged 408,605 bbl. daily throughout the year.

Starting in January with 11,039,817 bbl. exported, or a daily average of 356,123 bbl., exports increased gradually until the peak month of August, when 13,724,242 bbl. (daily average of 442,717) was reached. From September to December shipments declined slightly, shipments in December having been lowest because of the strike in the Lake Maracaibo district, when only 10,562,368 bbl. was shipped, or daily average of 340,721 barrels.

Details showing 1936 exports from all producing fields and giving names of participating companies are shown in Table 7. Total exports

TABLE 5.—*Production of Crude Oil, Venezuela, 1936*¹

	La Rosa Field				Lagunillas				Mene Grande	El Mene	Media
	L.P.C.	M.G.O.	V.O.C.	Total	L.P.C.	M.G.O.	V.O.C.	Total			
January.....	749,860	340,147	916,231	2,006,238	3,420,926	1,481,600	2,513,247	7,415,773	1,164,595	54,359	8,583
February.....	746,324	317,017	812,381	1,875,722	3,373,114	1,358,102	2,362,813	7,094,029	895,931	51,825	8,168
March.....	753,303	340,529	721,107	1,814,939	3,371,045	1,416,342	2,478,698	7,266,085	1,090,470	53,800	9,586
April.....	662,567	333,855	697,406	1,693,828	3,618,182	1,337,964	2,425,161	7,381,307	1,175,768	50,830	9,466
May.....	661,103	337,766	704,357	1,703,226	3,512,499	1,346,206	2,426,526	7,334,791	1,354,658	51,216	9,359
June.....	625,956	317,812	635,430	1,579,198	3,073,829	1,233,155	2,425,526	6,732,510	1,295,375	54,097	32,293
July.....	704,615	353,768	757,136	1,815,519	3,786,664	1,280,730	2,809,151	7,876,545	1,598,923	53,891	27,575
August.....	785,533	370,864	690,364	1,846,761	3,740,931	1,283,429	2,744,648	7,769,008	1,623,496	52,308	22,380
September.....	801,665	383,789	767,148	1,952,602	3,563,500	1,313,107	2,755,149	7,631,756	1,629,316	43,417	20,684
October.....	873,299	401,545	690,509	1,965,353	3,682,497	1,337,616	2,734,099	7,754,212	1,419,665	45,705	40,878
November.....	781,255	391,352	702,581	1,875,198	3,616,993	1,254,615	2,893,173	7,704,781	1,394,042	42,381	23,254
December.....	655,648	174,081	329,496	1,159,225	1,967,074	626,433	1,383,250	3,976,757	786,215	30,102	15,230
Grand total.....	8,801,138	4,062,525	8,424,146	21,287,809	40,727,254	15,269,299	30,001,001	85,997,554	15,428,454	583,931	227,456

¹ Converting metric tons crude oil to barrels:

La Rosa.....	6.91
Lagunillas.....	6.63
Mene Grande.....	6.69
Mene-Media.....	7.5
Tarra-Manuales.....	6.69
La Paz.....	7.00
Concepcion.....	7.00
Mene de Acosta.....	7.20

TABLE 5.---(Continued)

	Hombre Pintado	La Paz	Concepcion	Tarra	Los Manuales	Cumarebo	Quiriquire	Orocual	Pedernales	Amacuro	Las Palmas	Mene de Acosta	Total
	B.C.O.	V.O.C.	V.O.C.	C.D.C.	C.D.C.	S.O.V.	S.O.V.	S.O.V.	S.O.V.	S.O.V.	S.O.V.	T.O.V.	
January.....	1,520	12,656	110,098	364,759	75,811	221,907	1,653,330		550			x ³	13,090,189
February.....	1,725	16,912	95,669	296,634	70,914	224,822	1,729,235	1,715	506 ²			x	12,363,807
March.....	1,293	23,429	104,447	326,840	75,309	262,145	1,921,536	1,925	533			x	12,952,337
April.....	1,457	15,484	97,076	328,727	67,422	250,610	1,837,146	1,577	475			x	12,911,173
May.....	919	20,412	98,602	313,319	70,860	254,943	2,038,030	1,328	493	1,090		x	13,253,246
June.....	1,565	14,077	84,105	243,309	67,997	239,429	1,664,756	1,201	453			x	12,010,365
July.....	1,124	16,373	99,085	302,356	68,733	247,600	1,990,014	1,239	338	1,125	1,831	x	14,102,271
August.....	1,330	15,043	98,441	282,124	67,890	224,767	2,100,928	966	469	5,040	2,453	x	14,113,404
September.....	1,183	13,300	92,127	267,526	63,093	209,914	2,165,792		259	21,695	1,277	x	14,113,941
October.....	1,297	14,140	94,654	272,684	67,067	209,070	2,217,373			26,180	2,310	x	14,130,588
November.....	1,167	15,337	89,768	264,870	63,374	218,778	2,080,253			28,177	1,273	x	13,862,653
December.....	668	6,657	47,621	149,421	66,980	230,107	1,778,462			52,132	1,141	x	8,300,718
Grand total.....	15,248	183,820	1,111,693	3,412,569	825,450	2,794,092	23,176,855	9,951	4,076	135,439	10,235	24,290 ⁴	155,228,982

² Paria included.³ Estimated.⁴ Not available at time of compiling table.

TABLE 6.—*Production Records by Fields*

Field	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928
Mene Grande.....	225,783	367,304	258,478	526,119	1,498,052	2,397,602	4,757,152	4,860,482	6,362,151	8,443,418	9,818,296	13,287,716
El Mene.....								1,079,662	2,637,020	2,316,690	2,475,084	1,866,538
Media.....												
Hombre Pintado.....												
Ambrosio.....								3,212,134	729,317	1,729,317	1,272,323	23,124
La Rosa.....									10,899,278	21,215,300	19,309,649	1,969,327
Punta Benitez.....										133,684	1,146,278	26,106,656
Lagunillas.....										1,207,913	1,221,971	1,221,971
Concepcion.....									265,539	832,501	28,825,578	61,451,468
La Paz.....									286,103	734,280	633,782	195
Tarra.....										49,513	228,910	6,962
Los Manuales.....											107,188	135,485
Cumarebo.....												
Quiriquire.....												
Pedernales.....												
Amacuro.....												
Orocual.....												
Totumo.....												
Las Palmas.....												51,975
Urumaco.....												
Guanoco.....												
Netick.....								112,400	64,495	242,373	317,191	381,607
Mene de Acosta.....												
Total.....	225,783	367,304	258,478	526,119	1,498,052	2,397,602	4,757,152	9,264,678	21,243,903	36,904,989	63,134,279	105,503,024

TABLE 6.—(Continued)

Field	1929	1930	1931	1932	1933	1934	1935	1936	Total
Mene Grande.....	15,927,710	20,742,386	11,953,658	13,213,780	13,045,545	15,235,057	15,360,488	15,428,454	173,709,631
El Mene.....	2,015,234	1,888,263	1,768,930	1,739,437	890,390	751,987	724,695	583,931	20,737,861
Media.....					800,410	203,243	105,492	227,456	1,336,601
Hombre Pintado.....	39,163	26,935	25,221	23,046	16,192	16,694	17,276	15,248	202,899
Ambrosio.....	12,174,698	5,128,862	1,600,540	1,959,088	24,971,792	23,057,211	21,538,642	21,287,809	292,526,003
La Rosa.....	27,337,154	23,266,755	19,367,027	21,681,056					
Punta Benites.....	483,040	234,727	31,596	460,772					
Lagunillas.....	78,493,631	75,376,078	65,844,197	61,352,198	58,141,883	72,619,348	81,218,677	85,997,554	670,528,525
Concepcion.....	25,165	3,180,537	4,637,797	2,153,869	2,153,646	1,742,679	1,416,050	1,111,693	18,153,453
La Paz.....	57,181	279,470	662,810	414,253	281,451	241,367	169,736	183,820	3,546,343
Tatira.....	180,186	5,114,214	4,450,179	3,329,294	3,347,602	4,414,621	3,925,351	3,412,569	28,466,201
Los Manuales.....			3,196,800	3,009,744	4,260,085	2,038,387	1,119,336	825,450	14,449,802
Cumarebo.....			19,779	2,086,341	4,931,342	3,860,661	3,021,580	2,794,092	16,713,795
Quirquire.....	48,784	1,149,905	3,072,010	4,969,254	6,756,702	13,721,766	19,874,565	23,176,855	72,769,841
Pedernales.....						18,209	27,048	4,076	49,333
Amacuro.....						17,340		135,439	135,439
Orocual.....								9,951	27,291
Totumo.....	68,619	10,101	9,093	1,848					141,636
Las Palmas.....	16,279	28,410	114,353				4,854	10,285	174,181
Urumaco.....	88,180	91,707	25,185					205,072	1,855,805
Guanoco.....	442,317	248,663	46,759						55,118
Netick.....				55,118					844,482
Mene de Acosta.....	144,000	224,758	197,022	116,384	91,334	46,694		24,290	
Total.....	137,541,341	136,991,770	117,022,956	116,565,482	119,688,374	137,985,264	148,623,790	155,225,982	1,316,629,322

TABLE 7.—*Crude Oil Exports, Venezuela, 1936*¹

La Rosa Field						Lagunillas Field						
	Lago	M.G.O.	V.O.C.	S.O.V.	Cia. Esp. Pet.	Total	Lago	M.G.O.	V.O.C.	S.O.V.	Cia. Esp. Pet.	Total
January.....	583,630	120,408	818,009	36,918	18,575	1,577,540	2,934,289	1,131,922	2,242,431	393,926	51,225	6,753,793
February.....	645,633	217,432	731,984	34,349		1,629,398	3,008,087	896,940	2,520,214	342,454	32,937	6,800,632
March.....	637,671	342,018	757,617	34,294		1,771,600	3,212,647	1,002,942	2,472,953	424,265	65,745	7,178,552
April.....	559,869	402,391	635,327	32,047	19,630	1,649,264	3,414,099	872,648	2,356,292	354,089	50,921	7,048,649
May.....	620,890	245,551	799,786	32,049		1,698,276	3,533,501	872,868	2,425,551	403,278	50,241	7,285,439
June.....	788,349	346,324	551,468	33,744		1,719,885	3,473,533	866,563	2,510,213	306,811	32,750	7,189,370
July.....	671,260	510,603	656,131	32,173		1,870,167	3,610,561	863,735	2,621,238	381,222	45,705	7,522,461
August.....	619,381	525,800	693,681	34,630		1,873,492	3,989,035	840,213	2,724,913	381,717	50,358	7,986,236
September.....	821,368	402,818	687,405	33,083		1,944,674	3,753,222	825,898	2,574,914	346,102	33,535	7,533,671
October.....	743,910	335,693	676,280	36,118		1,797,001	3,472,569	991,436	2,642,648	420,584	53,584	7,580,280
November.....	816,710	374,395	686,933	33,703		1,911,801	2,962,717	859,819	2,822,133	389,421	52,666	7,086,756
December.....	802,174	173,681	621,089	16,061		1,613,005	2,794,299	465,581	1,611,193	135,575	17,571	5,024,219
Grand total.	8,315,845	3,997,114	8,315,770	389,169	38,205	21,056,103	40,159,259	10,490,565	29,524,593	4,279,444	536,697	84,990,558
						¹ Converting metric tons crude oil to barrels:						
						La Rosa.....	5.91					
						Lagunillas.....	6.53					
						Mene Grande.....	6.69					
						Mene-Media.....	7.50					
						La Paz.....	7.00					
						Concepcion.....	7.43					
						Tarra-Manuales.....	7.20					
						Mene de Acoosta.....	7.20					

¹ Converting metric tons crude oil to barrels:

La Rosa.....	5.91
Lagunillas.....	6.53
Mene Grande.....	6.69
Mene-Media.....	7.50
La Paz.....	7.00
Concepcion.....	7.43
Tarra-Manuales.....	7.20
Mene de Acosta.....	7.20

TABLE 7.—(Continued)

	Mene Grande	El Mene ¹	La Paz	Concepcion	Mene de Acosta	Tarra-Manuales	Cumarebo	Quiriquire	Guiria	Total
	C.P.C.	B.C.O.	V.O.C.	V.O.C.	T.O.V. ²	C.D.C.	S.O.V.	S.O.V.	S.O.V.	
January.....	843,250	58,370	15,613	80,374		432,312	158,714	768,730	351,121	11,039,817
February.....	574,737	56,105		88,633		459,252	308,862	922,823	901,087	11,741,517
March.....	745,708	54,698	16,765	115,872		424,315	133,852	983,826	892,192	12,118,380
April.....	935,226	57,097	34,267	131,273		420,713	308,180	1,463,526	882,881	12,374,266
May.....	1,128,961	55,861	10,641	98,910		371,838	357,009	1,583,031	702,750	12,994,716
June.....	1,340,926	76,315	17,285	113,891		317,832	136,410	1,833,472	753,169	12,479,825
July.....	918,534	74,645		80,022		354,840	329,125	1,163,170	671,288	12,376,252
August.....	1,245,166	77,542	17,958	114,722		429,457	163,974	1,901,325	974,370	13,724,242
September.....	1,082,185	77,064	18,165	77,394		417,210	165,511	683,867	1,175,211	13,164,952
October.....	1,165,327	97,562	15,605	79,098		365,974	281,053	873,867	1,123,759	13,379,570
November.....	1,023,651	80,250		98,738		356,707	225,894	771,842	1,039,419 ⁴	12,595,088
December.....	1,132,071	58,030	27,420	67,244		171,484	209,825	616,313	1,642,757 ⁴	10,562,368
Grand total.....	12,135,742	823,539	174,719	1,146,171		4,521,934	2,770,409	11,467,784	10,054,004	149,140,963

¹ Includes Media and Hombre Pintado crude.² No shipments made during 1936.³ Includes 16,104 bbl. Pedernales crude.⁴ Includes 65,721 bbl. Pedernales crude.

TABLE 8.—*Exports Record by Fields*

Field	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927
Mene Grande.....	57,096	143,880	14,309		997,643	1,813,452	3,344,428	4,575,484	5,916,035	8,260,779	7,909,387
P. Mene-Media.....								1,066,837	2,620,738	2,155,599	2,476,915
La Rosa.....								2,911,229	20,797,670	20,797,670	17,512,380
Lagunillas.....									797,590	26,895,232	26,895,232
Concepcion.....									283,609	1,422,040	633,782
La Paz.....									204,515		177,835
Guanoco.....									41,000		321,576
Mene de Acosta.....											
Tarra-Manuales.....											
Quiriquire.....											
Cumarebo.....											
Guiria.....											
Total.....	57,096	143,880	14,309		997,643	1,813,452	3,344,428	8,553,550	18,918,382	33,433,678	55,927,107

Field	1928	1929	1930	1931	1932	1933	1934	1935	1936	Total
Mene Grande.....	9,680,536	12,576,072	16,893,334	8,640,390	9,516,560	8,255,387	10,629,253	11,019,091	12,135,742	132,378,858
El Mene-Media.....	1,812,187	2,004,188	1,856,940	1,754,514	1,774,819	1,617,376	990,722	792,184	823,539	21,746,558
La Rosa.....	27,597,505	40,079,776	27,908,008	19,947,114	22,954,444	24,214,674	21,555,357	20,397,009	21,056,103	276,783,754
Lagunillas.....	58,445,581	72,431,744	77,347,534	67,451,418	60,949,932	58,882,944	70,984,747	80,888,259	84,990,558	660,063,639
Concepcion.....		25,152	3,197,019	4,599,713	2,090,215	2,069,926	1,708,770	1,377,457	1,146,171	18,553,854
La Paz.....		30,000	256,757	605,406	398,773	268,697	223,552	172,737	174,719	2,512,991
Guanoco.....	364,332	360,000	224,280	87,604						1,393,792
Mene de Acosta.....			171,948	137,689	89,081	99,896	11,311			509,925
Tarra-Manuales.....			4,984,719	7,350,873	6,112,010	6,972,697	5,229,387	4,983,995	4,521,934	40,155,615
Quiriquire.....			888,713	2,950,539	4,519,373	5,826,927	12,500,730	17,112,771	11,467,784	55,266,837
Cumarebo.....					1,970,443	4,874,343	3,793,412	3,058,775	2,770,400	16,467,372
Guiria.....								607,862	10,054,004	10,661,866
Total.....	97,900,141	127,506,932	133,729,252	113,525,260	110,375,640	113,082,867	127,627,241	140,410,240	149,140,963	1,236,502,061

from each field during 1936 are shown in Table 7. Percentages of participation were: Lagunillas, 57 per cent; La Rosa, 14; Mene Grande, 8; Quiriquire, 7.6; Guiria, 6.7; others, 6.7.

Combined exports from Quiriquire and Guiria terminals of the Standard Oil Company of Venezuela's producing fields in eastern Venezuela exceeded shipments from the La Rosa field, thus making that field second in rating as an exporter of Venezuelan crude, and placing La Rosa in third place.

Shipments from all fields for the period 1917 to 1936 inclusive, giving yearly totals as well as the grand total on Dec. 31, 1936, are given in Table 8. The percentages of participation of each field are as follows: Lagunillas, 53 per cent; La Rosa, 22; Mene Grande, 10.7; Quiriquire and Guiria, 5.3; others, 9 per cent. The cumulative total of 1,236,502,061 bbl. exports during the period 1917 to 1936 inclusive compares with the total accumulated production for the same period of 1,318,629,322 barrels.

Destinations of Shipments.—Crude oil from the producing fields and terminals listed above is shipped to deep-water terminals as follows:

Mene Grande Oil Co. (Lagunillas and La Rosa fields) to Las Piedras Terminals, Paraguana.

Caribbean Petroleum Co. (Mene Grande field) to Dutch Shell Refinery at Curaçao, N. W. I.

Venezuela Oil Concessions (Lagunillas, La Rosa, Concepcion and La Paz fields) to Dutch Shell Refinery at Curaçao, N. W. I.

Colon Development Co. (Tarra and Manueles fields) to Dutch Shell Refinery at Curaçao, N. W. I.

British Controlled Oilfields (Media and El Mene fields) crude sold under contract to Shell for delivery to Curaçao, N. W. I.

Lago Petroleum Corporation (Lagunillas and La Rosa fields) to Lago Oil & Transport Co. Refinery at Aruba, N. W. I.

Standard Oil Company of Venezuela (Cumarebo field) to Tucupido Terminal by pipe line for shipment to world ports.

Standard Oil Company of Venezuela (Quiriquire field) through Caripito terminal on San Juan River and by shuttle tankers to Guiria Terminal for shipment to world ports.

N. Y. & Bermudez Co. (Guanoco field) occasional shipments to U. S. A.

Tocuyo Oilfields of Venezuela (Mene de Acosta field) occasional shipments to world ports.

CRUDE OIL IN STORAGE JAN. 1, 1937

At the end of 1936, crude oil in storage throughout Venezuela amounted to only 2,232,152 bbl. as compared with about 6,469,348 bbl. at the end of 1935.

Steel tankage employed for storage of crude, fuel oil, etc., totaled capacity of 15,464,050 bbl., in 396 tanks ranging in size from 250 bbl. to 85,000 bbl. each, and distributed throughout all fields and shipping terminals. Storage capacities of the various companies are as follows:

	BARRELS		BARRELS
British Controlled Oilfields, Ltd.....	309,000	Tocuyo Oilfields of Venezuela	87,500
Caribbean Petroleum Co.....	1,474,500	Mene Grande Oil Co.....	5,575,000
Colon Development Co., Ltd..	546,950	Venezuelan Oil Concessions, Ltd.....	1,792,100
Standard Oil Co. of Venezuela	1,454,000	West India Oil Co.....	100,000
Lago Petroleum Corporation...	3,985,000	Coro Petroleum Co.....	20,500
New York & Bermudez Co....	115,000	Orinoco Oil Co.....	4,500
Total.....			15,464,050

At the end of 1936 there was available storage space for approximately 13,231,898 bbl. The small quantity of crude in storage at the end of December was due principally to curtailed production during December when such operations were suspended because of the strike. Shipments of the Mene Grande Oil Co. from lake fields to Las Piedras terminal were stopped on Dec. 14 and not resumed before the end of the year, whereas exports from Las Piedras terminal to world ports depleted accumulated crude in storage at that point.

PRODUCING FIELDS

As a result of 1936 developments, substantial extensions were made in the exploited portions of the Bolivar Coastal fields (La Rosa, Lagunillas and Mene Grande) as well as in eastern Venezuela (Quiriquire, Pedernales, Amacuro).

Lagunillas Field

This producing area contributed about 55.4 per cent to the total production for 1936, and about 57 per cent to the total cumulative production of Venezuelan fields, and was the scene of most activity in western Venezuela. It is in the District of Bolivar, State of Zulia, about 35 km. southwest of the older La Rosa field and about 45 km. northwest of San Lorenzo, the lake terminal port for the Mene Grande field.

The productive levels are correlated with the tar zone of La Rosa area, and comprise an interval of 200 to 300 ft. over a large part of the field. This interval may be divided into at least two oil zones of which the upper yields oil of 14.0° to 16.5° Bé. and the lower and most important 17.5° to 21.0° Bé. In the approximate southern two-thirds of the field, the lower zone directly overlies the Eocene surface and is believed to pinch out against the unconformity in an updip direction. A tar zone about 400 ft. thick containing oil of 11° to 12° Bé. is also present in the southern two-thirds of the field, the top of this zone being about 1000 ft. above the Eocene surface. In view of its thickness and wide extent, this zone contains a vast quantity of tar crude.

Including the Tia Juana area (7210 acres) and the Bachaquero area (4750 acres) and considering present productive levels, drilling to date

in the Lagunillas section has proved an area of about 48,075 acres, of which about half is under exploitation.

Production activities center in the operations of three companies in this area; viz., the Venezuelan Oil Concessions, the Lago Petroleum Corporation and the Mene Grande Oil Co., C. A. The first operates concessions on the mainland to the lake shore, the second operates concessions in the lake bed with exception of a strip 1 km. wide, which separates the Lago's holdings from those of the Venezuelan Oil Concessions. This strip is developed by the Mene Grande Oil Co.

During recent years only the Lago and V.O.C. carried out new drilling in Lagunillas, but in 1936 the Mene Grande Oil Co. resumed drilling and started an extensive program for drilling up its hitherto undrilled locations in the northern part of the field. Operations of the three companies were as follows:

Lago Petroleum Corporation.—This company maintained three strings of tools in this district throughout the year, drilling several wells in previously undrilled sections created by drilling of step-out wells the previous year. Four step-out wells were also drilled in the extreme west, some $8\frac{1}{2}$ to 9 km. out from the lake shore. Five wells were also drilled in the extreme southern section of Lagunillas. In drilling the four step-out wells to the west, a new producing zone was discovered almost 9 km. from shore, commercial oil sands being found in the marine La Rosa formation. This discovery well (LL-261) resulted in fairly large natural flow of light "Santa Barbara zone" crude with strong pressure, the well being completed at 4270 ft., with daily initial production of 1260 bbl. of 28.4° A.P.I. gravity. The average gravity of oil from this formation in Lagunillas is around 15.5° A.P.I.

In addition to its drilling program the Lago maintained several strings in work-over and repair jobs on old wells and several "wet" wells were repaired and recompleted.

The Tia Juana section of the Lagunillas field also saw renewed activity. Following the lead of the V.O.C., the Lago started drilling in the Tia Juana field after suspension of drilling in the area since 1928, when it was considered the district comprised an important future reserve of heavy oil. It is between the Lagunillas and La Rosa fields, and the tar zone of the La Rosa area, which consists of a thick body of soft, porous, oil-saturated sands, is the important productive level of the field. One well was brought into production during the year with an initial output of 1100 bbl. of 14.7° A.P.I. gravity. A second well was started but had not been completed by the end of the year.

During 1936 the Lago started 83 wells, of which 81 were brought into production, in addition to another that was spudded the previous year, making 82 completions. Average depth of wells was 3750 ft. in the northern section and 4400 ft. in the southern section of the field. Average

daily production of the new completions was 420 bbl. in the north and 835 bbl. in the south.

Average daily output was 110,350 bbl. in January 1936 and 116,675 bbl. in November. Total production of the Lago from the Lagunillas area, including Tia Juana, amounted to 40,733,015 bbl., as compared with 36,717,978 bbl. in 1935. The increase of more than four million barrels came from new flush production in the 82 wells completed, as well as from a total of 142 pumpers compared to 107 pumpers at the start of 1936.

Venezuelan Oil Concessions, Ltd. (Lagunillas, Tia Juana and Bachaquero).—This company operated seven strings in the Lagunillas district throughout the year, adding an eighth string to drill in the Bachaquero area during November. Work was divided between new drilling and work-over wells.

During 1936 the V.O.C. spudded in 84 wells in the Lagunillas area, including 66 in the Lagunillas field proper, 15 in Tia Juana and 3 in the Bachaquero area, of which 77 were producers, together with two wells spudded in 1935, making 79 producers and one well completed as a gas well. Average daily initial production of the completions was: Lagunillas, north 585 bbl., south 1000 bbl.; Tia Juana, 440 bbl.; Bachaquero, 470 bbl. Total production of the V.O.C. in Lagunillas area during 1936 amounted to 30,001,001 bbl. as compared to 26,712,249 in 1935, an increase of over $3\frac{1}{4}$ million barrels. Average daily production in 1936 ranged from 81,075 bbl. in January to 96,440 bbl. in November.

One completion of the V.O.C. in the Lagunillas field (No. 366) was of much importance, as it is the most easterly well yet drilled and was completed for over 400 bbl. daily initial production. Its completion proved up additional potential production in this field. Another important well was in the Tia Juana area, located farthest inland. The well made only 15 bbl. daily of 4.6° A.P.I. gravity oil and is considered probably the edge of the field. A 120-ft. fault is reported to cut right through this well. The La Rosa tar zone was well developed and appeared richly saturated with oil. The La Rosa formation was wet. The fault left the tar zone and La Rosa formation on the downthrow side.

In the V.O.C.'s Bachaquero well LB-1, reported to be 700 m. updip from the Mene Grande Oil Company's Lagunillas No. 1, the Younger Tertiary group was tested and made 690 bbl. of 13.7° A.P.I. gravity. The lower level in this well was tested later and resulted in 333 bbl., no gravity being reported.

The V.O.C. expects to install 36 pumping units in its Tia Juana field, 12 to be installed in 1937, and the remainder as and when new wells are completed.

Mene Grande Oil Co., C. A.—This company resumed drilling activities in the Lagunillas area after a lapse of several years during which repair work only and preparing wells for pumping were carried out. Its inten-

tion is to drill up all undrilled locations in Lagunillas as well as in La Rosa, and then transfer drilling operations to eastern Venezuela. Thirteen wells were spudded in and completed as producers during 1936, averaging 250 bbl. daily of 17.5° A.P.I. crude. Seven of the wells were put to pumping on completion, the aggregate production of the 13 completed in 1936 being 2619 bbl. daily.

The M.G.O. maintained a few strings in work-overs and re-completions during the year. Pumping installations increased from 161 on Jan. 1 to 188 at the end of the year, when several additional wells were being equipped for pumping.

Total production for the year amounted to 15,269,299 bbl., as compared with 18,052,435 bbl. in 1935, a decrease of about $3\frac{1}{4}$ million barrels. Average daily production ranged from 47,795 bbl. in January to 41,820 in November 1936. This decrease is partly due to the fact that no new drilling was started until the latter part of the year and the aggregate daily output of new completions averaging only 2619 bbl. was insufficient to counterbalance declining output of the field's production.

La Rosa Field

The general term "La Rosa field" covers the three formerly separate localities of Ambrosio, La Rosa and Punta Benitez, which have gradually been joined by drilling into one common productive field. It is about 35 km. northwest of the Lagunillas field and has a proven acreage of about 28,070 acres.

The La Rosa field operations are carried on by the Venezuelan Oil Concessions, Ltd., Lago Petroleum Corporation and Mene Grade Oil Co., C. A. In recent years only the Lago engaged in active new drilling, the other two companies confining such operations to work-over and repair jobs. In 1936, however, all companies were drilling actively.

Oil sands (19° to 29° Bé.) present in the marine Upper Oligocene strata have furnished nearly all of the recovery to date. As in the remainder of the Bolivar Lake Shore fields, the Eocene surface (unconformity) is usually the final depth objective. An impressive future oil reserve is contained in a 300 to 450-ft. zone of tar sands (14° to 18° Bé.) which directly overlies the Oligocene, has a wide areal extent and at present is being exploited in only a few wells. The landward limits of the La Rosa area oil zones have been fairly well defined, but their lakeward limits have not yet been determined.

Total production of all companies from the La Rosa field in 1936 amounted to 21,287,809 bbl. as compared with 21,538,642 in 1935.

It has been made known that the Mene Grande Oil Co., C. A., intends to drill up all its undrilled locations in the Maracaibo Lake district. The Lago Petroleum Corporation and Venezuelan Oil Concessions have also

advised that they would do likewise in view of the existing offset situation. The V.O.C. plans a total of 70 wells to be drilled in the La Rosa area during 1937 and the Lago has scheduled a similar number in the same area, both thus offsetting the drilling of the Mene Grande Oil Co. in the one-kilometer strip. Individual operations of the three companies were as follows:

Lago Petroleum Corporation.—From one to three strings of tools were engaged in new drilling in the La Rosa field during 1936. Drilling was confined chiefly to the eastern, central and southeastern parts of the field. Altogether 25 wells were started in 1936, 21 of which were producers, 4 completed but closed in for lack of production facilities. Average depth of the wells drilled was 2730 ft., and average daily initial production of the 21 new completions was about 8000 bbl. Average gravity of oil produced was 27.0° A.P.I.

Lago's production from the La Rosa field during 1936 amounted to 8,801,138 bbl. Average daily production ranged from 24,190 bbl. in January to 25,202 in November. Pumpers were increased but slightly during the year, or from 93 to 95, although several closed-in wells were equipped for pumping at the close of the year.

In the Punta Benitez section, 16 wells were spudded in during 1936, also one relief well. Of these, 14 were completed as producers together with one well started in 1935; a total of 15 completions. Average depth of wells drilled was 2775 ft., and average daily initial production of new wells was 528 bbl., gravity of the oil averaging 27.0° A.P.I.

In the Ambrosio section of the field no new drilling was carried on during the year. Production from both Punta Benitez and Ambrosio areas is included with totals of the La Rosa field.

Mene Grande Oil Co., C. A.—After confining its operations in the La Rosa district for several years to work-over and repair jobs only, the Mene Grande Oil Co. resumed active drilling towards the end of October in order to drill up all undrilled locations. Two wells were completed as producers with initial daily output of about 400 bbl. each.

Work-over and repair jobs were continued throughout the year, and preparation of wells for pumping. Pumping installations increased from 122 wells at the start of 1936 to 163 on Dec. 1.

Mene Grande Oil Co. production from the La Rosa area during 1936 amounted to 4,062,525 bbl., the average daily production ranging from 10,975 bbl. in January to 12,625 bbl. in February. The increase in yearly output can be attributed to the additional 41 pumpers installed, which effectively counteracted the natural decline in output of the field.

Venezuelan Oil Concessions, Ltd.—Little drilling was carried on in the La Rosa area by the V.O.C., and none until September, when one string was allocated for new drilling and work-over jobs. One new well was brought into production with output of 180 bbl. of 26° A.P.I. crude. A

second string was added towards the end of the year, but is engaged chiefly in repair jobs and preparing wells for pumping.

The share of the V.O.C. in La Rosa production during 1936 amounted to 8,424,146 bbl. Daily average production ranged from 29,620 bbl. in January to 23,419 in November, January being the peak month of the year. The daily average for the year was 23,080 barrels.

Mene Grande Field

The Mene Grande field, pertaining to the Caribbean Petroleum Co. of the Dutch Shell group, is situated on the east side of Lake Maracaibo about 17 km. inland from the San Lorenzo terminal and refinery of the same company. It is in the northern part of the District of Sucre, State of Zulia, and was discovered in 1914. Unlike other fields in the Bolivar coastal area, no offset situation exists, all acreage being owned by the Caribbean Petroleum Co.

Up to the beginning of 1936, a total of 277 wells had been drilled in this field. During the year 24 new wells were spudded in, of which 19 were producers, together with three others started in 1935. One well was completed as a gas well for repressuring purposes and four wells were still drilling at the end of the year.

Average depth of wells drilled ranged from 2650 ft., although wells completed in the southern part of the field averaged 3600 ft., and those in the west and northern parts averaged 2450 ft. Average initial production of the new wells was about 1400 bbl., and average gravity of oil from the new heavy oil wells was 17.1° A.P.I. Four strings of tools were in operation at the end of 1936. There are two oil levels, of which the most important is a thick zone present over the entire field, overlying Eocene shales, yielding heavy oil of 13.8° to 22.6° Bé., most of which averages 17.0° Bé. The second level is found in Eocene sandstones in a portion of the field and yields 28° to 29.1° Bé. oil. Edge waters have been noted in both levels.

For the first time in the history of the field, pumping was resorted to in September 1936, after experiments earlier in the year with two units. At the end of the year five wells were pumping and additional installations on five more wells are expected at an early date.

At the end of 1936 there were 133 wells producing; i.e., 58 flowing naturally, 70 on gas or air-lift and 5 pumping.

Total production from the Mene Grande field during 1936 amounted to 15,428,454 bbl., or daily average of 42,154 bbl. From 1917 to 1936 inclusive the Mene Grande field produced a total of 173,709,631 barrels.

Rio Tarra and Los Manueles Fields

Except for work-over and repair jobs, no new drilling was effected in this area of the Colon Development Co. (Shell subsidiary). Tarra pro-

duction for 1936 amounted to 3,412,569 bbl., and Manueles output was 825,450 bbl. The field is in the District of Colon, State of Zulia, about 85 km. inland from the lake shore line. Cumulative totals from 1917 to 1936 of both fields were as follows: Tarra, 28,466,201 bbl.; and Los Manueles, 14,449,802 barrels.

La Concepcion and La Paz Fields

No new drilling took place in these fields of the Venezuelan Oil Concessions on the west side of Lake Maracaibo in the District of Maracaibo, State of Zulia. Concepcion field is about 25 and La Paz field about 38 km. west and slightly south of the city of Maracaibo. The productive limits of either field have not been determined. During 1933, the date of last drilling, a deeper level was discovered in La Concepcion 101, yielding about 900 bbl. initial daily flow of 42.5° Bé. oil, but no other wells have been drilled in the new zone since then.

As of Jan. 1, 1937, La Concepcion production was being taken from three wells flowing naturally and 75 pumpers, while La Paz output came from one well flowing naturally and three pumpers.

La Concepcion production during 1936 amounted to 1,111,693 bbl. and La Paz 183,820 bbl. Total production from 1917 to 1936 of both fields was as follows: Concepcion, 18,153,453 bbl.; La Paz, 3,546,343 barrels.

Other Fields in State of Zulia

As in 1935, the two wells of the Netick field of Orinoco Oil Co., in the District of Mara, remained closed in. One of these is a small pumper and the other has a daily natural flow potential of 500 bbl. of 27.5° Bé. oil. The Totumo field, District of Perija, pertaining to the Standard Oil Co. of Venezuela, likewise remains closed in, and it is not expected that operations will be resumed in this area despite a reported potential production of 2300 bbl. daily, all equipment and material having been moved from the field.

British Controlled Oilfields, Ltd.

In the El Mene and Media fields operations were confined to the latter district. Four wells were spudded in the Media field up to the end of 1936, of which two were brought in as good producers, one was plugged and abandoned, and the fourth well was still drilling at the end of the year. One of the two producers had an initial daily output of over 2000 bbl., but settled down within a month to around 600 bbl. daily production. The second producer made over 1500 bbl. daily initial flush production but dropped to 550 barrels.

One string of tools was engaged on wildcat drilling during the year, on two locations. Work on one, Vega Oscura 1, was suspended to start

on the second (Lejia No. 1), which is to be drilled to ascertain potentialities of the field and if production may be obtained as far out as 3 km. from the Media field proper. Up to end of the year no definite results were obtained from either test.

Oil recovery from the El Mene field on Jan. 1, 1937, was being secured from 37 wells on gas or air-lift and 51 pumpers. In the Media field two wells were flowing naturally and five wells were pumping.

Production of the El Mene field during 1936 amounted to 583,931 bbl. and from the Media field 227,456 bbl. Cumulative totals of the fields from 1917 to 1936 were as follows: El Mene, 20,737,861 bbl.; Media 1,336,601 barrels.

Hombre Pintado Field

Operated by the British Controlled Oilfields, Ltd., only one well of this small field was pumped throughout 1936, producing 15,248 barrels.

El Mene de Acosta Field

This field is operated by Tocuyo Oilfields of Venezuela. Only one completion, a dry hole, was effected during 1936, and production was taken from 13 small pumpers during the year with a total output of about 24,290 bbl. The cumulative total of the field was 844,482 bbl. at the end of 1936.

Cumarebo Field

The Cumarebo field, in the State of Falcon, District of Zamora, only about 6 km. from deep water on the Caribbean, is operated by the Standard Oil Company of Venezuela, with the North Venezuelan Petroleum Co., Ltd., participating in royalty of 26.875 per cent, drawn chiefly in kind.

Nine wells were started in 1936, eight being brought in as producers and the ninth still drilling at the end of the year. Average depth of wells was 1575 ft., and average daily initial production was 385 bbl. Average gravity of output was 49.3 A.P.I. gravity. The aggregate daily initial production of the new completions amounted to 3080 bbl. Drilling was confined almost entirely to the southern and southwestern parts of the field and the known limits of proven acreage as at the first of January, 1936—about 470 acres—were not extended during the year's operations.

In November 1936 five additional wells were equipped with pumping units, making a total of six at the end of the year. An additional 12 units are to be installed early in 1937.

The Cumarebo field is small and accumulation in the several oil levels has been influenced considerably by faulting. Production for 1936 amounted to 2,794,092 bbl., or daily average of 7636 bbl., fluctuating from a high daily average of 8456 bbl. in March to a low of 6744 in October. Accumulated production of the field up to Jan. 1, 1937, amounted to

16,713,795 bbl. At the end of the year production was being taken from 35 wells flowing naturally and from 6 pumpers. One string of tools continued new drilling at the end of 1936.

Other Falcon Fields

Las Palmas and Urumaco fields were inactive during 1936, although Las Palmas had an output of 10,285 bbl. during the year when wells were temporarily opened. Urumaco remained closed in throughout the year. Both fields have natural flow potentials—Las Palmas, 800 bbl. and Urumaco 2000 barrels.

Quiriquire Field

The Quiriquire field is situated in the District of Piar, State of Monagas, and is owned exclusively by the Standard Oil Company of Venezuela. Drilling activities were divided in 1936 between exploitation drilling in the Quiriquire field and exploration or wildcat drilling in various districts. At the end of the year five strings were engaged in structure drilling and seven strings on wildcats.

Production is obtained from a fairly thick zone of soft, porous sands over the greater part of the fields, unconformably overlying Oligocene black shale, and at the northern edge of the productive area contacting Upper Cretaceous strata.

In the Quiriquire field 41 wells were started during 1936, of which 35 were completed as producers together with one well started during 1935. Two wells were plugged and abandoned as dry holes. Drilling was confined to the central, east central and southern parts of the field and little acreage was proven outside of the former limits, which comprised about 10,250 acres.

Aggregate daily initial production of the 36 completions amounted to 35,123 bbl. Production secured during 1936 amounted to 23,176,855 bbl., or an average of 63,325 bbl. The daily average throughout the year fluctuated from 53,333 bbl. in January to a high of 71,528 in October. Production for the previous year of 1935 totaled 19,874,565 bbl., or an increase in 1936 of 3,302,290 barrels.

Average completion time for the majority of the wells drilled in Quiriquire during 1936 ranged from 40 to 45 days; average depth of wells was 2795 ft., and average gravity of new completions during the year was 18.1° A.P.I. At the end of 1936, production was being taken from 89 wells flowing naturally and 27 pumpers. However, 31 wells were closed in or inactive, of which number 25 have potential production and 6 do not have potential production caused, in part, by lack of pumping facilities.

In the Orocuai field of the Standard, no new drilling was performed during 1936, and only 9951 bbl. was produced. The proven acreage remained therefore at about 975 acres, and of the eight wells drilled to date one is producing, though shut in, three are dry or junked holes, and four are abandoned producers. The five wells that have produced, however, have "proved" a relatively large area, and for that reason as well as future possibilities the area is considered as a new field.

WILDCATS

Considerable wildcat work was carried out by the Standard Oil Company of Venezuela in eastern Venezuela during 1936. Work was carried on not only on acreage pertaining solely to the Standard of Venezuela but on pooled acreage with the Pantepec of Venezuela, Cia. Español de Petroleos and Seaboard Oil Co., and also wells drilled for the Lago Petroleum Corporation. Wildcat operations were started in the year with six strings and increased to nine during the year. At end of 1936, seven strings were engaged in such work. Because of the importance on development of wildcats in widely separated areas, a brief outline of the wells spudded and drilled during the year follows.

San Juan No. 2.—This is a Standard of Venezuela well, spudded Nov. 27, 1935, located 30 km. northeast of the Quiriquire field. No oil shows were encountered in this well and it was plugged and abandoned as a dry hole on Jan. 16, 1936.

El Lirial No. 1.—This well is on Pantepec of Venezuela acreage, which later was transferred to the Standard of Venezuela to be drilled by the latter under contract, the Pantepec receiving an overriding royalty. It was spudded in 1935 and after being carried to 5237 ft. was found to be a dry hole, so was plugged and abandoned on Nov. 26, 1936.

La Canoa Nos. 1 and 2.—La Canoa was spudded in 1935 and after reaching a depth of 3855 ft. in March, 1936, operations were temporarily suspended, when it was decided to move to another well. La Canoa No. 2, located 20 km. northeast of No. 1, was spudded on Aug. 15 and by the end of the year had reached a depth of 4618 ft., operations being held up temporarily for receipt of materials.

Temblador Nos. 1 and 2.—Temblador No. 1, which is a Lago-owned well, drilled by the Standard of Venezuela under contract, receiving only the cost of drilling, was also spudded in 1935 and was completed at 4980 ft., plugged back to 3960 ft. on Oct. 10, 1936. It is understood this well was brought in as a producer but no details are available as to actual results. Temblador No. 2, also owned by the Lago and drilled by the Standard of Venezuela, was spudded on Oct. 27, and at the end of the year was coring at 5030 ft. These wells are from 10 to 15 km. immediately north of El Pilon No. 1 in the District of Sotillo, State of Monagas.

Amacuro Nos. 2, 3 and 4.—These are Standard of Venezuela wells, north of the Pedernales field and actually an extension of the field itself. They were formerly Pedernales locations but were renamed for administrative purposes, Venezuelan Seaboard Oil Co. having an interest in these wells. Amacuro No. 2 was spudded in on Dec. 30, 1935, and was completed at a final depth of 5380 ft., making more than 800 bbl. daily initial production. Amacuro No. 3 was spudded on May 27, being located 200 m. S. 31° W. of Amacuro No. 1. It was completed also at a final depth of 5380 ft. on Nov. 29, 1936, making 1072 bbl. daily initial production of 18.7° A.P.I. gravity oil. Amacuro No. 4, near No. 3, was spudded on Dec. 27, and at the end of the year was reaming for surface casing, total depth of hole being 230 feet.

El Salto Nos. 1 and 2.—El Salto No. 1, which formerly was known as Location Lot 61, No. 1, was spudded in on Feb. 11, 1936. The well is on former Pantepec property and was drilled under the same terms as El Lirial No. 1. It is about 40 km. east and slightly to the north of El Tigre No. 1 of the Mene Grande Oil Co., and 50 km. west in a straight line from El Pilon No. 1, the Lago well. It was completed at a final depth of 5219 ft., plugged back to 4536 ft. on Oct. 10, but it is not known whether any production was obtained from this well. El Salto No. 2, about 2 km. south and slightly to the east of No. 1, was spudded on Nov. 12 and was coring at 4275 ft. at the end of the year.

Chapapotal No. 1.—Located about 6 km. south and slightly to the east of Orocuál No. 2, this well was spudded in February 1936, although preparations were made at this location as early as October 1935. Delay was due to differences with the landowners, which were, however, straightened out. Upon reaching a depth of 6069 ft., the well was plugged and abandoned as a dry hole in August 1936. This was a Standard of Venezuela well.

Cotorra No. 1.—This is a Standard of Venezuela well about 200 m. north of Amacuro No. 1, and actually is in the Pedernales field. It was spudded on Aug. 22 and at end of the year was drilling at 5884 feet.

El Pilon No. 1.—A Lago well, drilled by the Standard of Venezuela under contract, the well is located in parcel Lago Lot No. 45 in the District of Sotillo, south of Temblador No. 1. It was spudded on July 18 and completed around Oct. 15 at a final depth of 3822 ft. No information is available as to whether or not production was obtained from this well.

Maturin Nos. 1, 2 and 3.—These wells are in the pooled area of the Cia. Español de Petróleo, Lago Petroleum Corporation, Standard of Venezuela, about 5 km. north-northeast of Maturin, these companies sharing in the following percentages: 25.751, 28.095 and 46.156 per cent, respectively.

Maturin No. 1 was spudded on July 22 but after reaching a depth of 919 ft. the well blew out and caught fire, burning chiefly gas but afterwards turning to oil with some gas still present. The derrick collapsed and the hole cratered. The fire was snuffed out at one time but because of danger from the high-pressure gas it was reignited. In the meantime, a relief well, Maturin No. 2, was drilled, and upon reaching the formation from which No. 1 was blowing out at a depth of 954 ft. in No. 2 well, water was pumped into the formation for two weeks and finally the fire was extinguished and the well killed. After cleaning up around the crater, Maturin No. 1 was plugged and abandoned on Dec. 23, 1936. Maturin No. 2, the relief well, remains "idle" at the end of the year, there being no indications as to whether or not this well will be completed. It is understood a considerable amount of oil was lost in the blowout of No. 1, but that the Standard of Venezuela has prospects for a good well in the replacement well, No. 3. This well was spudded on Sept. 29 and by end of the year had been carried to a depth of 2011 ft. when drilling and coring was being carried out.

Terreno Seco No. 1.—This well is also in the pooled area of the C.E.P.S.A.-L.P.C.-S.O.V. on the same basis as the Maturin wells, and is 38 km. north-northeast of the Maturin wells in the Caño La Viuda. It was spudded on Oct. 25 and after it had reached a depth of 2905 ft. the bit was lost in the hole. Attempts to recover it were unsuccessful and it had to be cemented in the hole. At the end of the year the hole had been cleaned out and preparations were in hand to drill ahead, the depth on Dec. 31, 1936, being at 2905 feet.

Tabasco No. 1.—This well is 20 km. east and slightly south of Temblador No. 1, a Pantepec well, drilled by the Standard of Venezuela under contract with Pantepec. It was spudded on Nov. 21 and at end of the year was drilling at 4058 feet.

At the close of 1936 the Standard of Venezuela had two other wildcat locations in hand; viz., San Juan No. 3 and Cotorra No. 2, neither of which, however, had been spudded in by Dec. 31, 1936.

Summarizing wildcat operations in 1936, the Standard of Venezuela spudded in 14 new wells in the year, of which number three wells were completed (two being brought into production and the third for which we have no information) together with two wells (Temblador No. 1 and Amacuro No. 2) which were spudded in 1935 and completed in 1936; four wells (including two from 1935) were plugged and abandoned; eight wells were still drilling at end of the year; one well was temporarily suspended (La Canoa No. 2) and one well (Maturin No. 2) being a relief well on which data are not at hand as to whether or not a completion will be effected later.

An even more intensive wildcat drilling program is anticipated by the Standard of Venezuela during 1937.

Up to the end of December 1936, the Mene Grande Oil Co., C. A., has drilled seven wildcats in eastern Venezuela; namely, Oficina No. 1 (spudded February 1933 and suspended at 6184 ft. as an uncompleted test on Dec. 6, 1933); Oficina No. 2, spudded in February 1934, at 4 km. north of No. 1, and also suspended as an uncompleted test on Aug. 4, 1934; at 6700 ft.; Aero No. 1, spudded Jan. 7, 1934, and suspended as an uncompleted well March 25, 1934, at 4477 ft., and the subsequent wildcats which are described in detail in the following paragraphs.

In the State of Anzoategui, eastern Venezuela, the Mene Grande Oil Co., C. A. (formerly Venezuela Gulf Oil Co.) started 1936 with one string of tools on wildcat work, but increased this to three strings before the end of the year.

This program is to be continued in 1937 with possibility of being increased considerably when undrilled locations in the Maracaibo Lake Basin district are drilled up. It has been indicated that the Mene Grande Oil Co. intends to transfer drilling operations to eastern Venezuela when this has been accomplished.

During 1936, work was either started or continued from 1935 on the following wells:

Santa Rosa No. 1.—The Santa Rosa No. 1 well, in the District of Freites, was started in 1934 and by May 9, 1936, had reached a depth of 7213 ft., and was sidetracked to 5900 ft., when it was plugged and abandoned as a dry hole. The well was classified as a "geological test."

El Tigre No. 1.—This well, in lot V-121 in the District of Freites, was spudded in June and by end of the year had reached a depth of 6425 ft. The well is now standing at that depth and no information as to results is at hand. However, it was reported as having been tested in November, making only salt water.

Santa Ana No. 1.—This well was located in the District of Aragua, 45 km. southwest of Santa Rosa No. 1. After reaching a depth of 6100 ft., the well was tested but with negative results. At depth of 6207 ft. operations were suspended pending further instructions, and the well is standing at that depth, although it is understood the local management recommended its abandonment.

Merey No. 1.—Operations at Merey No. 1, which was spudded in May 1934 and suspended in September of the same year, were resumed with the addition of the third string of tools in November 1936. The well was cleaning out until the end of the year, the depth remaining at 5855 ft.—the same depth as when it was suspended in 1934. The well is 31 km. east and slightly south of El Tigre No. 1 in the District of Freites.

LAKE TANKER TRANSPORTATION

The Dutch Shell group increased its lake tanker fleet during the year 1936 from 29 to 32 vessels. These additions brought the carrying

capacity of the Shell fleet up from 61,680,000 bbl. to 73,200,000 bbl. In addition, the Shell operated two tankers of the Arend Petroleum Mij., with total carrying capacity annually of 4,884,000 bbl., thus making the grand total for Shell tankers of 78,084,000 bbl. carrying capacity yearly. It is understood three additional tankers are to arrive early in 1937, each having a normal capacity of about 28,000 barrels.

The Lago Petroleum Corporation increased its tanker capacity from 21 to 22 vessels during the year, but in December transferred one tanker for service in the Argentine. This vessel, however, is to be replaced by one of similar capacity early in 1937. The Lago fleet has a carrying capacity of about 53,178,800 bbl. annually. During 1936 the Lago also chartered several tankers of the Mene Grande Oil Co. to augment the carrying capacity during special periods when its own fleet could not keep up with required shipments. Two additional tankers are being built and should reach Venezuela during June 1937, each having capacity of about 24,500 barrels.

The Mene Grande Oil Co. (formerly Venezuela Gulf Oil Co.) made no changes in its tanker fleet during the year, carrying capacity remaining at around 32,538,000 bbl. yearly. However, seven of its tankers were laid up most of the year, being surplus to shipping requirements, and some of these for short intervals were chartered to the Lago.

The Standard Oil Company of Venezuela had in service during the year three tankers in shuttle service carrying crude from Caripito Terminal on the San Juan River (Quiriquire crude) to the new Standard deep-water shipping terminal at Guiria, and also for hauling crude from the Cumarebo field to either Caripito or Guiria.

GEOLOGICAL AND GEOPHYSICAL INVESTIGATIONS

During 1936 considerable geological and geophysical work was carried out in widely separated areas by several companies. At the end of the year several such parties were active in the following districts:

In the State of Barimas, formerly known as State of Zamora, a torsion balance party was working in the District of Sosa for the Venezuelan Petroleum Co. Two seismograph parties were reported working for the Caracas Petroleum Corporation in the District of Infante, State of Guarico, and a geological party was reported in eastern Guarico for the Socony-Vacuum Co., also a magnetometer party in south Anzoategui. Seismograph work was under way for the Standard of Venezuela in southern Delta Amacuro and southern Monagas, in addition to torsion balance work in eastern Guarico as well as magnetometer work, and a geological party was reported working on the Roscio concession in Guarico.

In the Netick area, where the Orinoco Oil Co. has a shut-in field, it is understood the Lago had a seismograph party at work, and the Shell group had geological parties working in Tachira, eastern Guarico and

Zamora. A seismograph party and a "rainbow" party was reported working for the Shell in eastern Guarico, torsion balance work going on also in southwestern Monagas and Barinas, State of Zamora, and a Holwek balance party in Anzoategui, as well as seismograph work in the District of Colon near the Rosario field. A geological and magnetometer party was reported working for the Mene Grande Oil Co. in Anzoategui, as well as seismograph work in Monagas.

ACTIVITY IN LANDS

Although various companies reduced their holdings in Venezuelan acreage in some areas, and the Venezuelan Government cancelled delinquent concessions as well, the general tendency has been to increase holdings, especially on the part of the principal companies. Exact figures for the year are not at hand but over a three-months period figures published in the *Gaceta Oficial* (Government official gazette) listed a total of 812,550 hectares purchased by the most prominent companies during that short period.

Districts in which such acreage was purchased are for the most part in eastern Venezuela—viz., the States of Anzoategui, Monagas, and Guarico—although some purchases were made in the States of Zulia and Trujillo in western and central Venezuela, including a group of parcels south of the Mene Grande field comprising some 20,000 hectares.

An announcement was made during the latter part of the year that a port on the Caribbean known as "El Chaure," between the Mene Grande Oil Co. port of Guanta and Puerto de la Cruz, was sold to the Cia. Consolidada de Petroleo, subsidiary of the Venezuelan Petroleum Corporation.

Of interest also was an announcement by the Venezuelan Government in December that it had approved a petition of the Venezuela Gulf Oil Co. for transfer to the Mene Grande Oil Co., C. A., of a total of 849,377 hectares of acreage in the States of Zulia, Trujillo, Falcon, Anzoategui, Monagas and Guarico, for exploitation purposes, and 287,508 hectares in the States of Anzoategui, Guarico and Monagas, for exploration purposes. It is understood the acreage involved in this transfer covers the entire property of the Venezuela Gulf Oil Co., and the transfer to the new company, specially formed, was for legal purposes, the new company being registered in Venezuela and therefore not liable to certain taxes, etc., as it would be if the property had remained under the name of a company formed outside of the Republic of Venezuela. Similar steps had previously been taken regarding the marketing departments of the Shell and Lago, the Shell having organized the Petroleum Utensils Co. and the Lago forming the Compañia Petroleo de Lago.

During September, it was reported a new agreement had been entered into by the Standard Oil Company of Venezuela and the Lago Petroleum

Corporation whereby on all acreage of the Standard of Venezuela in eastern Venezuela the Lago will receive one-third share while in all Lago interests in western Venezuela, which includes the Maracaibo Lake Basin, the Standard of Venezuela receives one-third share, shares to be paid in either oil or cash as optional with either party. Such shares are to be based on book costs.

ACKNOWLEDGMENT

The author wishes to acknowledge his indebtedness for many data contained in the preceding pages, to Mr. Fred Hulsmeier of the Mene Grande Oil Co., Mr. D. B. Williams of the Caribbean Petroleum Company, and Mr. D. C. Porterfield of the Lago Petroleum Corporation, and wishes to express his thanks to Mr. H. F. Finch and Mr. Arthur R. Reich for their assistance in preparation of this paper.

Chapter VI. Petroleum Engineering Education

Problems and Objectives of Petroleum Engineering Education

BY LESTER C. UREN,* MEMBER A.I.M.E.

(Fort Worth Meeting, October, 1936; New York Meeting, February, 1937)

TODAY, a dozen or more universities and colleges in the United States are offering curricula designed for the specialized training of engineering students who plan to enter the petroleum industry. Many hundreds of students are following these curricula in their academic preparation, with the expectation that by so doing they will be better equipped to enter the petroleum industry in an engineering capacity than their competitors that seek to do likewise with training of less specialized character. Those who have helped plan and develop these curricula believe that such specialization should and does afford the student a superior preparation for his task. Others have questioned this and urge a broad preparation in fundamentals without specialization. Still others are suggesting even greater specialization than present petroleum engineering curricula afford. Some would have the student first prepare himself in one of the more general divisions of engineering, such as civil, mechanical or electrical engineering, and then seek some degree of specialized preparation in a graduate program.

Which of these views is correct; or, if there is merit in each, which plan offers the greater advantage to the student? It is time that we paused to take stock of our objectives and of our way of attaining them. Is the training received by our petroleum engineering students what it should be? To what extent is the product of our petroleum engineering schools meeting the requirements of the industry? How may graduates be better equipped for the work they are called upon to do? These are questions that educators interested in the training of petroleum engineering students are ever asking. They must depend upon engineers and executives engaged directly in the industry for advice and helpful suggestions in better planning the training to be offered to our future engineers. This paper will have served its purpose if it is successful in focusing attention of men active in the industry on some of these educational problems, to the end that the ideas of men close to the needs of the industry may be made known to those who have responsibility in the control of our educational programs.

Manuscript received at the office of the Institute Sept. 8, 1936.

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CURRICULA IN TRANSITION

We must not assume that our petroleum engineering curricula are standardized or fixed, in the sense that they have reached a permanently established prescription of subjects to be taught and a necessarily proper allotment of time between the different subjects. It should be recognized, rather, that our curricula are still in transition; that we are concerned with the needs of a rapidly developing and changing industry, and that what is conceded to be a well balanced program today may not necessarily be correct five years from now. In academic work, we are prone to be content with the existing order of things. We are reluctant to undertake drastic changes; and yet this path may lead us gradually away from our intended objective. It is desirable that we occasionally clear away the dead wood of past effort and realign ourselves with our objective. With minds free of past interests and prejudices, we should seek that which is best; not so much with the intent of projecting the past into the present as with the purpose of orienting our present thoughts toward the future needs of engineers entering our industry, in so far as we are able to visualize them.

THE FIELD OF THE "PETROLEUM ENGINEER"

Possibly we would not all agree on just what the duties of the petroleum engineer should encompass; therefore we would differ somewhat on the character of training that he should receive. Broadly, the writer considers the field of the petroleum production engineer to include all phases of technologic work that occur in an oil field from the time that the first test well is located until the last barrel of oil is shipped and the wells are abandoned. This concept provides the production engineer with a rather clear-cut field of endeavor, beginning where the exploration geologist leaves off on the one hand and ending at the point where the transportation interests take over the product for transport to the storage centers and refineries. Of course, the production engineer must know something of the methods of the exploration geologist and something of storage and pipe-line transportation of oil and gas. Some of the fundamental data regarding the properties and behavior of petroleum and gas he must share in common with the refinery engineer.

In thus broadly defining the field of the production engineer, it will be understood that no man can encompass in his training a detailed knowledge of and familiarity with all technology involved in the development of oil fields and the production and handling of oil and gas. We must depend upon highly trained specialists for some phases of the work. For example, the production engineer is not expected to be a trained micropaleontologist or geophysicist, though he must have a general understanding of these highly specialized sciences and must know the

ways in which they may usefully be applied in oil-field work, and how to use the information that they afford. Similarly, mechanical, electrical, chemical and civil engineers may be pressed into service when certain phases of the work present highly specialized problems requiring an intimate knowledge of the subject matter of these professional fields. If a power plant is to be designed and installed, the petroleum production engineer should not be expected to do the detailed work: a mechanical or electrical engineer especially qualified in this type of construction would be employed. Or, if a natural gasoline extraction plant is to be installed in the field, a chemical engineer experienced in this class of work would be expected to design and install, and perhaps also to operate it. Nevertheless, the petroleum engineer must be broadly familiar with the character of work contributed by these different classifications of engineers and must have a thorough understanding of the results of their work, insofar as they relate to and are tied in with his own. He must be first an engineer, secondly a petroleum engineer. He must have an essentially practical type of mind, trained to analyze problems, gather necessary data and arrive at proper conclusions from their analysis.

Though many regard petroleum production engineering as a rather specialized field of endeavor, it is really quite the reverse. There are few occupations that present a greater variety of problems or that require a broader preparation to successfully cope with them. The petroleum engineer must be something of a mechanical engineer, civil engineer, electrical engineer, mining engineer, geologist, geophysicist, metallurgist and economist, all rolled into one. His daily routine may bring him into contact with problems requiring application of a knowledge of any one of these professions. In common with other engineers, he must have a thorough grounding in the fundamental sciences: physics, chemistry and mathematics. He must have the usual engineering preparation in surveying, drafting, hydraulics, strength of materials, thermodynamics and analytical mechanics. Because his theater of operations is largely underground, he has many interests in common with mining engineers, particularly the geological sciences. He needs a broader preparation in the field of chemistry than those engaged in other engineering fields, with the exception of chemical and metallurgical engineering.

THE BALANCED CURRICULUM—HOW MAY IT BE ACHIEVED?

With this concept of the field of the petroleum engineer in mind, let us now briefly consider some of the problems that arise in planning an academic preparation appropriate to his needs. First, how are we to achieve proper balance between the time devoted to each of the many different subjects that must find a place in the petroleum engineering curriculum? How are we to determine just what proportion of the total time available should be devoted to geology; how much to physics,

chemistry and mathematics? How far should the student be led into the realm of analytical mechanics, thermodynamics and hydraulics? How much of the related fields of civil, mechanical, electrical and mining engineering should he include in his preparation? How shall we seek a proper balance between the time devoted to fundamental and applied science? How far shall we encourage specialization in the particular problems of the petroleum industry? These are questions upon which no two educators or petroleum engineers would entirely agree, and yet we must seek substantial agreement by compromise between opposing views if we would find a middle ground upon which to rear our petroleum engineering curriculum.

It is rather interesting to trace the influence of different individuals and departments on the curricula offered by different universities and colleges. Some of the early petroleum engineering programs were outgrowths of economic geology curricula, and in institutions where the geology departments have been dominant in developing instruction in petroleum technology, it is common to find the petroleum engineering curriculum overloaded with an excessive prescription of courses in geology. When the engineering departments have taken the initiative in formulating programs, it is usual to find the emphasis on mechanical engineering subjects, sometimes almost to the exclusion of the geological sciences. Where the pendulum has swung far toward the side of the so-called fundamentals, we find what seems to be an overemphasis on the methods of approach to our problems afforded by physical chemistry, thermodynamics and hydromechanics. Such men as Herold, Lacey and Lewis have demonstrated that these methods are broadly applicable to many of our problems, but in our enthusiasm for these new aids we must not lose our sense of proportion and balance. There is another type of academician who has a penchant for economics: who sees only the economic aspects of our problems and who is inclined to demand a share of the student's time for courses of economic nature that can only be provided at the expense of his fundamental and applied science courses. Lately there have been those who would impose upon our petroleum engineers a larger emphasis on sociology and political science. Again, there is the educator that harps on the necessity for developing a better "cultural" background for engineers and that emphasizes the importance of languages, history and philosophy, but that sees little of cultural value in the applied sciences.

We should not be critical of these different viewpoints, for there is something distinctly beneficial in each. We must find a middle ground between these apparently conflicting interests, each seeking an inordinate amount of the student's time and effort. Certainly, the engineer must be a cultured, educated person. He should be able to express himself intelligently and conduct himself properly in polite society. No good

citizen should be unmindful or uninformed of the great social forces that are at work in the world today, some of which would profoundly change the entire basis upon which the conduct of our engineering work is performed. Of course, every engineer must be an economist. But first of all, he must be on intimate terms with the natural sciences upon which the edifice of the engineering art has been reared. He must be thoroughly trained in the doing of those things that an engineer must know how to do in the conduct of his daily work.

May we not look upon the fundamental sciences, mathematics, physical chemistry, geology, drawing and the more fundamental engineering subjects as the "tools" of the engineer? Without them, he can do nothing. But even when he has his tools he must still become proficient in their use before he can be a successful engineer. And the engineer will not rise to his full responsibilities until he has acquired that breadth of understanding of the world of affairs that is conferred by a background of preparation in the fields of economics, sociology and political science. To properly express to others his personality and ideas, he must acquire proficiency in oral and written expression in his native language and at least a speaking acquaintance with one or more others.

Some months ago, the author wrote letters to ten of his former students: men that had spent a number of years in the industry and had advanced to positions of responsibility and presumably were able to appraise the reasons for their own success. They were asked what gaps they had discovered in their academic preparation and what courses they had found most useful in their professional work. As might have been expected, there was little agreement among these individuals and no two had precisely the same viewpoint. Some wanted more geology, some less. Some had found need for better preparation in fundamentals; others thought more stress on the specific problems of the industry would be preferable. Some felt the need of more training along mechanical lines; others thought more time should be devoted to human relations, economics and so on. Each spoke in the light of his own experience; and the important thing that stood out in this survey was the fact that no two had had the same set of experiences.

This leads us to the question of whether we are justified in attempting to rigidly standardize the preparation of young men entering the industry, if later they are to follow different paths and meet different requirements, particularly since few can foresee where their opportunities will lead them. If the latter is true we might reasonably be led to build engineering curricula largely of fundamentals, devoting our energies chiefly in the direction of developing in our students the power to reason, to analyze and apply these fundamentals in the solution of case problems illustrative of the type with which the petroleum engineer has to deal. Such a plan might be safely followed, with the assurance that we are at least strength-

ening the ability of the student to cope with his future professional work, wherever his opportunities may lead him.

Such a conclusion, however, does not solve the whole problem, for we are still confronted with the question of what proportion of the student's time shall be devoted to training in fundamentals, and what part to training in their application: the old question of a proper balance between fundamental and applied science. Some educators apparently believe that an equal division of time between these two phases is justified. Others would place the ratio at three to one or three to two. That is, three years of a four-year course would be spent on fundamentals and one on applications; or, in a five-year program, three years on fundamentals and two on applications. At any rate, it seems reasonably clear that if the engineering student is to be given an adequate grounding in mathematics, physics, geology, chemistry, drawing, surveying, analytical mechanics, hydraulics, strength of materials, thermodynamics and the necessary fundamentals of civil, mechanical and electrical engineering, at least three years will be necessary for the task, assuming that a proper foundation has been provided in the secondary schools.

HOW MANY YEARS SHALL THE PETROLEUM ENGINEERING CURRICULUM REQUIRE?

Perhaps the whole question of whether the petroleum engineering curriculum should be planned as a four-year, five-year or six-year program may be answered by deciding whether the training in applied science in the chosen field of specialization should span one, two or three years. Most educators active in the petroleum engineering field today would probably agree that one year is scarcely enough. Two years would be much better. Three years can scarcely be justified unless we are trying to build research men of Ph.D. caliber. Unfortunately, institutions that have attempted to pioneer six-year engineering courses have been unable to hold their students. Many leave after four years and do not return for what is, in most cases, a vital part of their preparation planned for the fifth and sixth years.

If we concede that a five-year program is desirable, it is perhaps of little consequence whether it be a five-year undergraduate program or a four-year undergraduate program followed by a graduate year. The former plan permits of better organization and assures that all students complete the full program before being awarded a degree; but the latter plan, with the graduate year leading to the Master's degree or Engineering degree, would probably be preferred by most students. This plan, however, gives encouragement to the many students who would be content with four years, omitting the fifth, thus leading to two classes of graduates: the partly trained four-year men later competing with the better prepared five-year men. Employers, unfortunately, do not always

intelligently discriminate between these two groups, and there is thus a misunderstanding concerning the degree of preparation that the employer might count on in employing graduates of our educational institutions.

RESEARCH

There is a difference of opinion concerning the place of research in the petroleum engineering curriculum. Should we prescribe an undergraduate thesis to be conducted as an individual project by each student? Or, should research be confined to graduate curricula? Perhaps the best that can be said for the undergraduate thesis is that it is a satisfactory introduction to research methods and, in some cases at least, cultivates a liking for investigative effort in the student that often stimulates him to undertake more competent research in a later graduate program. Incidentally, it affords the student an opportunity to explore some problem, aside from the prescribed routine, in which he may be particularly interested. It is one of his few opportunities for self-expression. Every assignment that the engineer undertakes in his professional work requires him to gather and analyze data; perhaps to carry on some planned experimental routine, and finally to prepare a formal report. The undergraduate thesis also follows this same pattern and, to this extent, is valuable in demonstrating the manner of approach to engineering problems.

It must be admitted that such work, when performed by most undergraduate students, is scarcely to be dignified by the name "research." Few students are able to conceive of and acceptably carry through a thesis, and the instructor must become a veritable fountain of ideas and inspiration if he is to keep his students busy with individual problems. Undergraduate thesis work is expensive instruction, both in the time consumed and in the cost of materials and necessary shop assistance. Yet, it is believed that with an inspirational teacher it can be a highly profitable type of work. Looked upon as the instructor's contribution to the field of research and as a means of extending his own knowledge, the time necessarily devoted to supervision and planning of many details is amply justified.

As for graduate research, it will probably be agreed that the institution that fails to support and encourage research among its graduate students, and to demand a certain amount of activity in this direction among its faculty personnel, is falling short of its proper objectives. Unless the research spirit is nurtured in our universities, the fountainhead from which springs the inspiration and enthusiasm that feed and support our industrial research organizations will be cut off. It may be reasoned that the universities, with their limited research budgets, cannot hope to compete with the great industrial research organizations; but the personnel to carry on the work of these research organizations must receive

their training in research methods and the inspiration and liking for research activities in the universities.

FIELD STUDIES

Another question has been under consideration in most petroleum engineering schools: Should observation field courses be included in the university program, or should it be left to the individual student to arrange his own field contacts? Certainly, from the standpoint of the student who is often unable to find short-period employment in the oil fields, or who is unable to negotiate the right of entry into field plants and properties, faculty-conducted field excursions are a great advantage. A well planned and conducted field-observation course is of great educational value, and affords an opportunity for gaining an all-inclusive picture of equipment used and conditions presented in the field that we are not able to convey to the student as satisfactorily in any other way. The best time for such a course would be during the summer vacation period between the third and fourth years of a four-year course, or between the fourth and fifth years of a five-year course. There is then some opportunity for preliminary instruction of the student concerning what he is to see and do in the field, but the major part of his more advanced petroleum engineering instruction would come in the year following the field course.

While the field course may thus be an interesting and valuable adjunct of the academic curriculum, the difficulties in the way of offering and conducting such a course often seem unsurmountable. Many students are unable to afford it. Such a course must usually be given during the summer vacation period and both student and faculty personnel are reluctant to give the extra time and effort necessary. For the student that is partly self-supporting, it means not only extra expense but also time that might be used in earning essential funds for continuance of his academic work. In deference to such students, field courses are usually made optional, with the result that university authorities must plan and assume the preliminary financial obligations, without knowing in advance the number of students that will elect the work.

Some years ago, Professor George, now of the University of Pittsburgh, made what seemed to many an excellent suggestion. He proposed that one university in the Mid-Continent region, one in the Appalachian region and one in California, should offer each summer, a comprehensive field course that might be patronized by students from all parts of the country. A student might spend one summer vacation period in each region during his undergraduate course, thus gaining an understanding of the problems presented and methods and equipment used in each. Owing to lack of initiative on the part of the universities and colleges, the plan proposed has not yet been achieved. Perhaps the A.I.M.E. or the

American Petroleum Institute could assist to some extent in promoting this activity.

VACATION TIME EMPLOYMENT OF ENGINEERING STUDENTS

The educational institutions must depend upon industry to afford students the opportunity to become familiar with the practical aspects of oil-field work. This may be accomplished by permitting them to make observations of routine operations in the field, or by actually employing them to assist. The latter plan, of course, is best from the standpoint of the student, particularly if the employer will cooperate by moving him about and giving him a variety of assignments. Actual employment of students during university vacation periods also appeals, inasmuch as it permits needy students to earn a part of the cost of their academic education.

Some employers are reluctant to employ students because the few weeks or months that they have between college sessions do not permit them to become really proficient in their work. Though eager to learn and willing to work, students may be more of a liability than an asset from the point of view of the employer. While we must agree that the average student is not likely to be a profitable employee during the first few weeks of his employment, yet from a long-range point of view his employment may be entirely justifiable. Every employer has the problem of finding suitable personnel for the technical jobs in his organization. By employing students during vacation periods, the employer may learn enough about them individually to intelligently select those he may wish later to take into his permanent employ. Vacation time employment of the student thus affords a basis of mutual acquaintance and often develops a sense of loyalty that later may lead to a life-long profitable relationship.

From a broader point of view, employers have a moral obligation in assisting the colleges and universities in developing trained technical personnel for industry. This obligation cannot be met entirely by merely offering the student the opportunity for employment after he leaves the university, for he needs practical contacts during his college course. The student that has not had opportunity for such contacts is seriously handicapped in his academic preparation in comparison with his more fortunate fellows that have had the benefit of some practical training in industry.

Several of the larger oil companies are offering petroleum engineering graduates practical training on an apprentice basis, with the purpose of selecting the better men for permanent positions. During the apprentice period, which may occupy a year or more, the men are moved about so that they have contact with many different phases of oil-field work and are given supervision and instruction by several different executive officers. Such a plan offers many advantages both to the individual and the oil company. The writer, however, would urge that the apprentice

relationship be initiated a year or more prior to graduation from the university—say during the summer vacation period immediately preceding the last undergraduate year. By so doing, the practical and academic preparation of the student may be better coordinated and the student may be better aligned with his objective.

SUMMARY

In the foregoing pages, an effort has been made to define the objective of petroleum engineering education and to outline some of the problems that are a matter of concern to educators in training students to attain this objective. No conclusions are to be offered as an outgrowth of this discussion. Instead, the writer prefers to conclude with a few questions, it being his hope that the discussion presented and questions raised may provoke expressions of opinion from others.

1. What is the proper field of the petroleum engineer and what character of academic preparation is likely to best equip him for the work that he is expected to do?

2. What percentage of the petroleum engineering student's time in his university course should be devoted to fundamental science training and what part to applied science training?

3. What percentage of the time devoted to applied science in a petroleum engineering curriculum should be in the general fields of engineering and what part may profitably be devoted to the specialized technology of the petroleum industry?

4. How many years should the undergraduate university curriculum in petroleum engineering span?

5. Is graduate training necessary for the petroleum engineer, and if so, how many graduate years are desirable?

6. Should research be included in the undergraduate petroleum engineering curriculum, and if so, toward what objectives should it be directed?

7. Should universities conduct observational field courses for petroleum engineering students and, if so, should they be a part of the prescribed curriculum?

8. How may relationships between the schools and the industry best be adjusted to foster mutual interest and participation in the training of engineering students for the petroleum industry?

9. How can the gap between the colleges and industry be bridged so that the student may transfer from university work to industrial employment with minimum loss in continuity of interest and purpose?

Petroleum Engineering Education

By W. W. SCOTT,* MEMBER A.I.M.E.

(Fort Worth Meeting, October, 1936)

THE application of engineering methods to the problems connected with drilling and producing in the oil industry has led to the development of the science that is variously termed "petroleum engineering," "production engineering," "petroleum production engineering," and even "political engineering." It would require much detail to enumerate the qualifications of a petroleum engineer, just as it would for an engineer in any major industry.

For those who have a genuine liking for the oil industry, there is a wide selection of pathways to achievement. The oil industry is now highly specialized. Its products are necessary to all civilized people and are indispensable in the security of our nation and also in the well-being of our families. The business structure of our country depends in a large measure upon oil, and the welfare of this group as individuals is certainly linked with the welfare of the oil industry.

WHAT IS THE TREND OF ENGINEERING?

The oil industry offers a fertile field of opportunity for engineering; probably more so than any other industry. The sciences of geology, physics, chemistry and mathematics are all used in some phase of the oil industry and to a very considerable extent in the production division, which embraces the geological, drilling and producing departments. In drilling and production alone, research programs of considerable magnitude are being carried on at this time, and no doubt the future will see a great deal more of this kind of work. Through the cooperation of the engineer, the equipment manufacturer, and the American Petroleum Institute, immense savings have been made by the standardization of drilling and production equipment. Drilling equipment in itself offers a wide scope for study, in that continued efforts are being made to improve the equipment so that it can be made to drill faster and to greater depths. The improvements in drilling equipment are required because new reserves of oil are being found at progressively greater depths. In order to produce such oil in competition with oil now being produced from reservoirs

Manuscript received at the office of the Institute Sept. 24, 1936.

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of lesser depths, it is necessary that the costs of drilling for and producing such oil be kept as low as the handicap of the additional depth will permit. Such improvements require a thorough knowledge of the equipment in order that refinements may be made along the lines of sound engineering principles, the application of which is bringing about better balanced equipment, with each individual part designed to properly take care of its purpose, and deficiencies as well as cumbersome overdesign in equipment are being eliminated. Wells are now being drilled to a depth of about two miles. Thirty-five years ago, a well 3500 ft. deep was considered to be of a great depth. Research in equipment will include much work in the study of alloys for the purpose of manufacturing equipment that will stand abuse and have much greater strength. The mechanical engineer will be called upon to design new equipment, and the drilling technician will be obliged to improve methods and technique in drilling and producing.

One of the many important studies with regard to drilling is that of mud-fluid control, which probably is now in its infancy. Much is expected by continued research and study of this phase of drilling, wherein the drilling to greater depths and through formations presenting difficult problems will be greatly facilitated.

Drilling costs have been materially reduced during the past few years. For instance, the 3300-ft. shallow sand wells of the Raccoon Bend oil field were drilled during 1928 and 1929 in an average time of 72 days, at an average cost of \$32,000 per well. During 1934, a deeper sand was discovered in this field at 4100 ft. and these wells require about 20 days to complete at a cost of \$22,000 each. Thus it is seen that improved technique and equipment have made it possible to drill 800 ft. deeper for \$10,000 less per well.

Likewise, drilling to depths of 9000 to 10,000 ft. is not prohibitive, since drilling costs can yet be further reduced. I do not hesitate to predict that drilling costs will be cut in half during the next 10 years.

With reference to the actual producing of oil, perhaps the greatest accomplishment has been the recognition of the principles relating to the efficient utilization of reservoir energy in the operation of wells and pools. By reservoir energy is meant: (1) gas energy in the free gas in the higher portions of the reservoir, and gas dissolved in the oil; and (2) the hydrostatic pressure of edge and bottom water in the lower portions of the reservoir below the oil. The most efficient utilization of these factors results in the greatest ultimate recovery of oil.

Further consideration of the benefits to be derived from the utilization of reservoir energy in producing oil brings out that there is a certain balance between investment, recovery, rate of recovery and cost of producing, which must be determined in order to operate a given oil pool

successfully, and the technical man is much better prepared to render this service than anyone else.

I am sure that the advantages to be gained by rational development programs and then by producing at rates of withdrawal in keeping with reservoir conditions, are obvious. Many recall the discovery of the deep pools in the Los Angeles Basin some 11 years back, and later, Seminole in Oklahoma, and then the Oklahoma City pool. It was often remarked, "Why discover deep oil pools when the cost of producing them will be prohibitive?" In those days, 15 to 20 per cent of the ultimate production was recovered by flowing and the remainder by pumping. Today, with new fields developed under proration and with proper attention given to utilization of reservoir energy, it is not unreasonable to expect a recovery of 80 to 100 per cent of the recoverable oil by flowing. Thus depth has ceased to be so great a factor in lifting costs.

There is yet unlimited possibility for work with one outstanding problem—increased ultimate recovery. It is generally accepted, and in numerous instances it has been proved, that for every barrel of oil produced there are approximately two barrels of oil left in the ground. In connection with this problem, additional work must be done on the physical properties of oil and gas as they occur in a reservoir, together with their behavior under various reservoir conditions. Additional information obtained through study and partial solution of these problems will give a better understanding of the proper methods to use in drilling for and producing oil.

Repressuring and water-flooding are old methods, familiar to most of us, yet they still require study and research for much needed greater improvements.

Technicians have constructed their own special instruments for obtaining the knowledge that we now have of reservoirs and reservoir contents. These instruments are much in need of improvements and accessories. For instance, there is the pressure bomb, which is used to take pressures in oil wells and formations, and there is gas-sampling and fluid-sampling equipment. Laboratory equipment used in any of these problems needs to be perfected, and the technique of handling most of these problems in the laboratory will be improved as additional time and effort are given to them.

In this brief summary of the trend of engineering activities within the industry, an attempt is made only to show that much has been accomplished and that the problems of the production division of the petroleum industry are now such as to offer a wide range of opportunity for young engineers. Moreover, the many young engineers that are being taken into the industry from year to year are good evidence that the petroleum engineering graduates have done commendable work.

WHAT SHOULD THE UNIVERSITY DO?

Before the university can outline courses for students and prepare them for the oil industry, it is important that the industry's requirements be fully understood.

Petroleum engineering includes all engineering work in the production department. For the engineer, it might be said that there are two general pathways to achievement in production work, which come under the divisions of field engineering and specialized technical engineering. Each of these groups requires a distinctly different type of mental make-up. The successful field engineer is the one that can work harmoniously with his fellow workers and that possesses the quality of leadership. His make-up probably is largely determined by inheritance and training before he reaches the university, but it can be aided and developed by the university. Graduates of most of the engineering schools and of the science courses are about equally suited under the present system of university curricula for this type of position. The petroleum engineering graduates from most such schools are usually more suited for this type of position than for the highly specialized technical positions or for achievement along technical lines. This type of engineer, during his early years, gets experience through manual labor in the various positions of drilling and production. Following his field work, he may be assigned to duties as a district or field engineer. In this position, he acts as a technical assistant to supervision but he is not required to have a high degree of technical training for such work. He acts also as an intermediary between the specialized technical groups that are located in the home offices and the field offices. There is usually a cooperative arrangement between such field engineers and the specialized technical engineers, whereby each is a necessary assistant to the other. After several years of such experience, the field engineer can determine whether he is better suited for the field work, which leads to supervisory positions in production work, or for specialized technical work. The experience he has gained is necessary for progress in either field engineering or specialized technical work.

The type of engineer that finally enters specialized technical engineering usually starts out with more or less of an idea that he is better suited for the specialized technical job, but his training and experience are much the same during the earlier years as that of the field engineer striving to gain a supervisory production position. The successful specialized technical engineer usually is found among graduates of other engineering schools besides petroleum engineering, and only a small percentage of petroleum engineering graduates finally enter specialized technical work because in most cases they do not have sufficient technical training along

the line of specialization. The engineer coming within this group particularly can greatly enhance his value to himself and the industry by specialization in the university for one or two years beyond his four-year course, if he has found himself especially adaptable to working with certain problems of the industry.

It would seem that it should be the purpose of the petroleum engineering school to prepare young men for the field engineering or technical positions, and to develop within the student such interests or aptitudes as he may have along the lines of fundamental sciences; so that he will be enabled to pursue other routes to achievement if he finds, after graduation, that he did not wisely select an engineering curriculum.

This points to the conclusion that many of our college courses are overspecialized, and that, after all, a degree in petroleum engineering is not necessary to success in petroleum engineering work. In our present system of education, a student must decide not later than the beginning of his junior year the course he wishes to take. This forces upon the young man an important decision before he has had sufficient experience to qualify him to make such a decision. If he definitely plans to study for four years only, the effect of this is not particularly serious; but if later he should wish to return to school for graduate work, he must either follow the course of study he took as an undergraduate or spend valuable time satisfying undergraduate requirements in the field in which he wishes to specialize. It appears that this system works a hardship on the student in forcing him to make a decision as to his field of future endeavor before he is prepared to do so. Much of this could be avoided if the first four years of college were devoted to broader training.

The field of engineering, like the fields of medicine and law, is becoming so highly specialized that it is impossible to give in a four-year course all of the culture-developing, theoretical, and practical courses that are desirable for the technical expert; yet the colleges continue to attempt to turn out trained engineers in the short space of four years. The result is inadequate training in the field of engineering and no training at all in the other fields, which possibly are as important as technical knowledge. Industry itself is probably responsible for this unfortunate situation. Industries have demanded technical graduates dignified with a degree of Bachelor of Science in their particular branch of engineering. They have deluded themselves into believing that colleges can take over their job of turning out men to handle their particular problems and have sought to dodge the responsibility of training their own men. This delusion has perhaps been shared by the colleges themselves, with the result that the ability of the college graduate often is overrated both by industry and by the graduate himself. Such a situation usually leads to disillusionment and discouragement of the men, who leave college believing that the road to success is paved with sheepskins.

It is difficult to suggest remedies for an unfortunate condition that has become so important a part of our educational system. Perhaps it would be remedied if engineering education were to require a six-year course. It should aim to give, in addition to engineering, a broad training in culture, scientific habits of mind, and mental elasticity through class discussion and laboratory practice. Such a course would prepare the college student to handle technical jobs in the petroleum industry or almost any other industry. Such men would be better trained for engineering work than the average college graduate of today. A few months in the oil field, working during the summer months, will give the engineer all the practical drill needed. It is needless to say that the education of the petroleum engineer never ends—his life is not one of ease.

WHAT SHOULD THE STUDENT DO?

It is unfair to place the full burden on the university; the student should bear his part. First, he should free himself from domination by his parents. Not that it is always to his detriment, but often parents are too close to their children to visualize properly their potentialities. Next, the student should analyze himself to determine whether he has the personal characteristics necessary to be a success in engineering. He should make an effort to obtain an education sufficiently broad in principles that may be applied to producing and drilling technique to enable him to be the best, because he will find competition keen. He should have a high standard of mental honesty and a profound regard for the ethics of his profession. He should ask himself if he has the ability, horse sense, character, adaptability and perseverance requisite to an honorable and successful career in this profession. If he has any doubt, he should not risk a false start but should at once search elsewhere for his true vocation. Finally, the engineer should early realize that he owes much to his profession because he has profited by those who have gone before him and created the store of technical knowledge upon which he draws. He should at all times give consideration to the good name and dignity of the profession he has adopted as his life work. The engineer should not attempt to advance his own interest at the expense of other members of the profession by merely distorting facts. This is mental dishonesty.

Above all, he should develop initiative and learn to use it properly. In it lies the secret of success. To me, no better definition of this characteristic has been given than that by Elbert Hubbard when he wrote:

The world bestows its big prizes, both in money and in honors, for but one thing . . . And that is Initiative. What is Initiative? I'll tell you: It is doing the right thing without being told.

But next to doing the right thing without being told is to do it when you are told once. That is to say, carry the Message to Garcia!

Next, there are those who never do a thing until they are told twice: such get no honors and small pay.

Next, there are those who do the right thing only when Necessity kicks them from behind, and these get indifference instead of honors and a pittance for pay. This kind spends most of its time polishing a bench with a hard-luck story.

Then, still lower down in the scale than this, we find the fellow who will not do the right thing even when some one goes along to show him how, and stays to see that he does it: he is always out of a job, and receives the contempt he deserves, unless he has a rich Pa, in which case Destiny patiently awaits around the corner with a stuffed club. To which class do you belong?

Combination Field Work and Class Work

By R. L. LANGENHEIM*

(Fort Worth Meeting, October, 1936)

COOPERATIVE education for engineers is based on the premise that theory and practice are inseparable in training men for the engineering profession, and the two must be advanced simultaneously in order to train men most successfully and efficiently. The teaching of theory obviously should be done by the college but the practice must be obtained in the field where the application of the theory is made.

The ideally trained engineer is one that knows theory, can apply the theory to practice, can direct, and work with, his fellow men. The old four-year plan of training engineers does a fair job of teaching the underlying theory of engineering but neglects entirely the training necessary for application of the theory, except through laboratory experiments, and the training in adjustments necessary to direct and work with men.

An engineer, like a lawyer, doctor, dentist or other professionally trained man, cannot practice until he has had practical experiences that give him a knowledge of the other phases of his profession. The doctor serves as an interne, the lawyer reads law in the office of a practicing attorney, and the engineer must enter the profession as a laborer or as an apprentice, unless he has had the advantage of a cooperative education.

Cooperative education provides the opportunity for the coordination of practical and theoretical training for the engineering profession throughout the period of training and thus eliminates many that are unfit to enter the profession, giving them an opportunity to seek other fields for which they may be better fitted, and reduces the overhead in industry that results from a large turnover of men not fitted for the profession.

THE COOPERATIVE PLAN

Cooperative education in engineering is no longer an experiment. It was inaugurated at the University of Cincinnati in 1904 by Dean Herman Schneider, and has worked successfully ever since. Over twenty schools offer this type of education and many thousands of young men have had the opportunity to receive their technical training under this plan.

Under the cooperative plan a student attends class for a period of eight weeks, then enters industry for eight weeks, maintaining this schedule

Manuscript received at the office of the Institute Sept. 8, 1936.

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throughout the year. He has an alternate, who follows the same program in the opposite order. The class work is repeated each eight-weeks period, so that a student and his alternate miss no classroom work and at the same time the job in industry is filled continuously. The work periods are considered as much a part of this educational training as the theory taught in class, and a student is expected to do satisfactory work on the job in order to receive his degree.

The direct and indirect benefits of cooperative education are threefold: to the student, to the industry and to the school.

The student receives a balanced program of theoretical and practical training, showing the interrelationship of theory, practice and labor essential to the development of a successful engineer. He is also provided with educational and vocational guidance. The material is presented under the same conditions that the engineer will find in practice. Second, the income derived by the students assists many of them to meet their financial obligations. Third, the student has the opportunity to associate with graduate engineers, thus giving him a broader view of the profession while he is still in the formulative stage of development, and also giving him intimate contact with industry, which provides him with an insight into labor problems and gives him a knowledge of the reactions and psychology of the working man that is invaluable to the engineer in industry. Through actual observation and practice, the student is forced to realize the economic as well as the technical side of engineering. He also establishes a primary market for his services.

Industry has the opportunity to train men for their particular field and has prospective employees that have proved their ability to handle the work and their interest in it.

The school benefits in that upon graduation students are placed in positions that they are capable of handling. Second, space and equipment requirements are halved because only one-half the number of students is in school at one time. It provides the school with an extensive laboratory consisting of the equipment of the firms that use the cooperative students.

COOPERATIVE COURSE AT TULSA

The cooperative plan is used by the College of Petroleum Engineering of the University of Tulsa in training engineers for the petroleum industry. A four-year course is offered, of which the first two years consist of the regular standard two 18-week semesters. When the student has completed all the requirements of the first two years, he becomes eligible for the cooperative work and is placed on this work during the summer preceding his third year. The third and fourth years are on a cooperative basis. The periods of alternation are eight weeks each and continue for 52 weeks each year.

During the first two years, the student is taught the basic mathematics and science for all engineering work. Beginning with the third year, the specialized courses incident to the petroleum field are introduced simultaneously with the student's introduction to the practical applications in the field and refinery.

Production students are placed in the field as helpers and roustabouts and as their training advances are changed to more responsible positions. Refining students start in plant-maintenance gangs and are promoted into positions carrying some responsibilities as they develop sufficiently to handle the work.

Chapter VII. Refining

Developments in Refinery Engineering in 1936

By WALTER MILLER,* MEMBER A.I.M.E.

WITH returning prosperous conditions in all industries, oil-refinery engineering has found opportunity for the more extensive application of improvements developed during the several years of depression. The year has brought out little of an entirely new nature, but much in wider application of previous worth-while developments.

The greatest volume of work done has been in modernizing the distillation and cracking units of existing refineries, particularly by substitution of combination skimming and cracking units for older equipment, and the installation of cracking plants in smaller refineries where formerly only skimming was practiced. A number of entirely new refineries were installed during the year, two of the most important being the 20,000-bbl. refinery by the Atlantic Refining Co., at Atreco, Tex., and a 12,000-bbl. plant by the Wilshire Oil Co., at Norwalk, Calif., these two embodying some of the latest developments in cracking and treating.

Total refining capacity for the United States is now reported as being something over 4,000,000 bbl. per day, but a movement is on foot looking to a complete revision of these figures, as experience has indicated not only some overstatement of capacity of equipment but that considerable equipment is included which because of obsolescence and location will probably never be run again. The 3,000,000-bbl. figure which the industry reached during the year's high consuming period required the operation of probably 95 per cent of the country's efficiently usable capacity.

CRACKING AND POLYMERIZATION

There were no new outstanding developments in the cracking field, progress being made largely in the further refinement of known principles. Improvements in furnace design and operation have been largely in permitting closer control of the heating curve through the cracking-tube system, assisting in more uniform yield and in the lessening of coke deposition, and permitting longer trouble-free operating time as well as reduction in furnace-maintenance cost.

Actual operating polymerization capacity has been increased little during the year, but a number of projects have been started, some nearing completion, the production from which will be available during 1937.

Reprinted from *Mining and Metallurgy* (Jan. 1937).

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Among these installations may be mentioned a 1200-bbl. plant at the new Atlantic Refining Company's refinery at Atreco; a 2000-bbl. unit in the Humble Oil Company's refinery at Baytown, Tex.; a 5000-bbl. installation at the Pan-American Company's refinery at Texas City, Tex.; and three or four units, aggregating 4000 bbl., of the Phillips Petroleum Co. Another project initiated this year, which will be completed in 1937, is the building of a 400-bbl. unit on the property of the Shamrock Oil & Gas Corporation in the great gas fields of the Panhandle district of Texas near Amarillo, which will process natural gas from that field through a plant combining a heating coil for cracking the gases and the catalytic polymerizing method developed by the Universal Oil Products Co. The cost of processing equipment so far developed for polymerization has been too high to permit of its consideration for comparatively small quantities of raw material. However, the close study being given to the economic and engineering features and the greater experience that will come from the operation of the plants being installed will undoubtedly result in improvements that in time will make this method of producing motor fuel of high octane value more generally commercially feasible.

"Re-forming," the cracking of the more undesirable, low octane value fractions of straight-run gasoline, has continued as an active factor, with a number of installations made during the year, in spite of the lowered cost of tetraethyl lead, and the greater permissible limits of ethyl lead inclusion in nonpremium gasoline. If higher octane standards are adopted the trend to re-forming will undoubtedly be augmented.

Something of a bombshell was thrown into the octane race situation by the announcement of the Ethyl Gasoline Corporation, on Oct. 27, giving its licensees an optional method of testing octane value, and raising the limit from 70 to 73 octane for nonpremium gasoline, and from 76 to 79 octane for ethylized premium gasoline. Protest was aroused because the new testing method was much more expensive and burdensome and was without approval of the various testing organizations and committees, and because the change in specification involved on the average at least two octane numbers higher than the existent 70 octane number ceiling, based on the present approved testing method. After a number of conferences the Ethyl Gasoline Corporation agreed to postpone the effective date for a period of at least 90 days to permit further study of the proposal.

TREATING CRACKED GASOLINES

In the field of treating cracked gasolines a number of additional installations were made of clay vaporphase treating units, most of them to operate in conjunction with combination units. The previously noted installation of a plant combining the Halloran low-temperature acid-treating method with the Stratford short-time-contact centrifugal opera-

tion, was completed during the year at the new Wilshire refinery and has been in successful operation for several months

A number of installations of the "Perco" process for sweetening gasoline were made. One method employs cupric chloride in solution and another uses it as a deposit on fuller's earth or other base, both methods being continuous and depending upon the addition of oxygen for operation.

It is understood that an arrangement has been made for making available to the industry the method of sweetening developed by the Standard Oil Company of California, using lead sulphide as the active agent for converting mercaptans into nonodorous products.

PRODUCTS FROM PETROLEUM GASES

Gradual but definite progress toward manufacture of increasing variety and volume of chemical products from petroleum gases was evidenced, and knowledge of the possibilities is growing so rapidly as to insure a greatly accelerating increase of development. Special extracts having decided cyclic characteristics were commercialized as varnish and lacquer diluents. Isopropyl ether as an ingredient of plus-100-octane aviation gasoline in conjunction with tetraethyl lead was put on the market. In the way of purely chemical production it is rumored that the Carbide & Carbon Corporation plans a large installation at Baytown, Tex., to utilize gases from the Humble Oil & Refining Company's refinery, similar to the operation at Whiting, Ind., carried on by the same company, using Standard of Indiana refinery gases.

The threat of forced blending of alcohol and gasoline is kept to the fore through the activity of the Chemical Foundation in advancing money for the rehabilitation of an idle alcohol plant in Kansas, and undertaking to arrange for the distribution of the blended motor fuel. The outcome of the venture will be followed with great interest, particularly in view of reported dissatisfaction abroad with alcohol-gasoline blends.

FUEL AND LUBRICATING OILS

An outstanding feature of the year's developments is the effect on refinery runs of the constantly greater use of furnace oils, largely for house heating, estimated by some at 16 per cent over 1935, or about 15,000,000 bbl. increase. This is causing refiners to run at higher rates than other products indicate, and if the winter of 1936-37 should be unusually severe and protracted, will undoubtedly result in the building up of larger gasoline stocks than otherwise would be needed. In view of the expected large increase in gasoline demand during 1937, probably straining refinery capacity to produce, this may not be an unmixed evil.

In the lubricating oil field few if any new developments are worthy of note. Additional capacity was installed in the way of solvent dewaxing, solvent treating, and vacuum distillation units. A fairly large-sized

operation, utilizing the solvent principle of acid-treating lubricating oil stocks at low temperatures in the presence of propane, mentioned in this review in 1935, has been put into operation, but no information regarding the results is available. Some progress has been made in the development of corrosion inhibitors to offset the apparent higher corrosion rate of the highly refined, solvent-treated oils. Nothing of a scientific nature has been published, but two products are being offered, others are being developed, and if successful may have some influence in changing the still slackening trend of solvent-treating installations. Use of addition agents to increase oiliness and bearing-pressure characteristics is increasing.

The trend of the 1937 cars seems to be toward higher bearing pressures, but in at least two models steps have been taken to reduce to some extent crankcase temperatures. A marked trend toward the use of hypoid gears, both because of manufacturing problems and the facility for more easily lowering the center of car gravity, to eliminate or reduce drive-shaft tunnels, brings to the front in greater degree the problem of special hypoid gear lubricants of the violent extreme-pressure type.

Additional extension of Diesel fuel application in heavy-duty engines took place, as was expected, although not on as broad a scale as would have occurred had the product been more widely available.

INSTRUMENTS AND MATERIALS

Some further refinements and improvements in both measuring and control instruments have been developed and offered.

In the field of corrosion-resisting materials there was announced in the latter part of the year the "Ihrigizing" process, named after its inventor, H. K. Ihrig, a high-temperature furnacing operation somewhat resembling case carburizing. By its means the surfaces of finished steel parts are impregnated with silicon to a material extent, and corrosion and heat-resisting properties superior to both stainless steels and the 4 and 6 per cent chromium alloys are claimed. Laboratory tests seem to bear out the claims, but no commercial experience in the refining industry is yet available.

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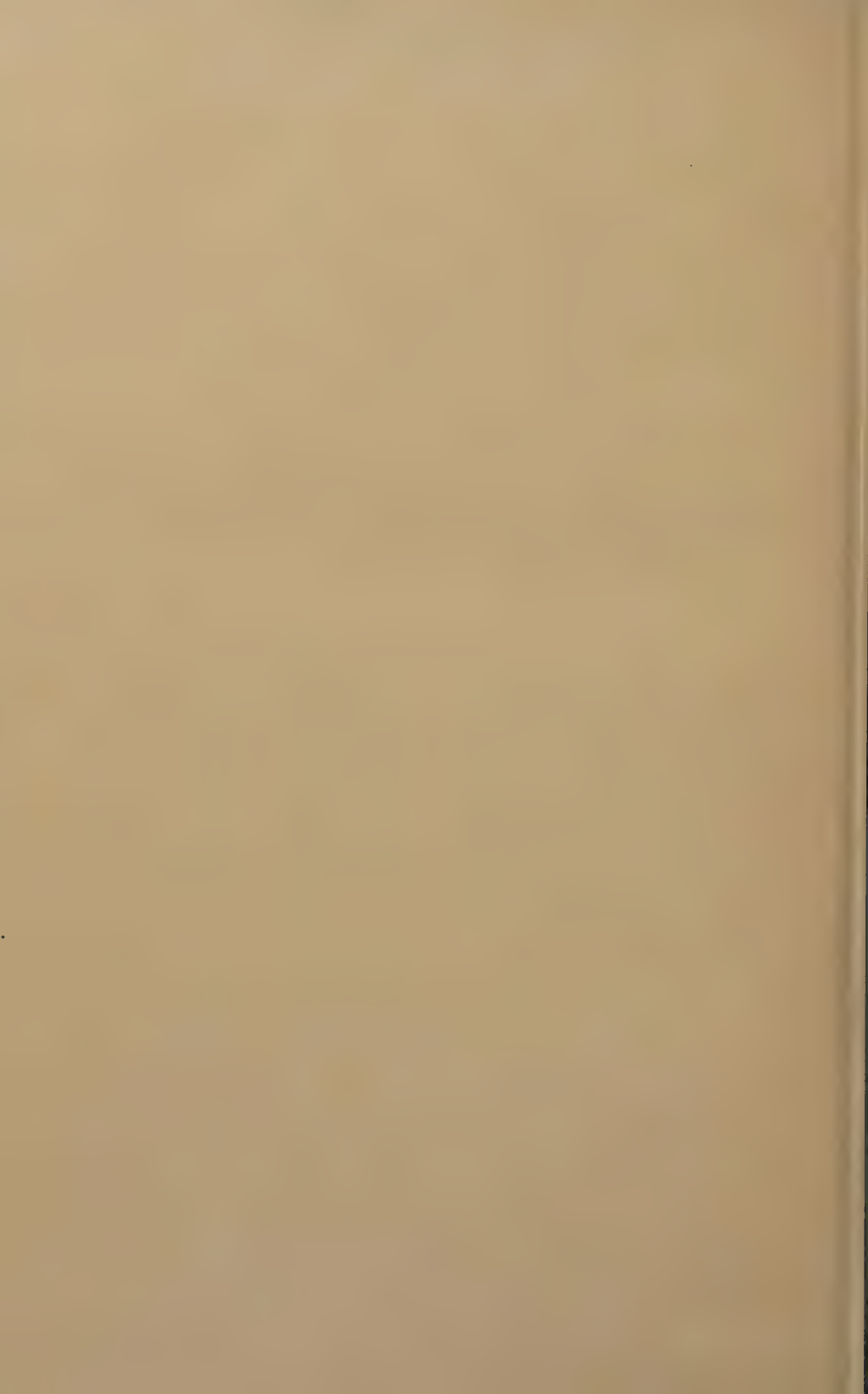
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